Lecture Notes in Networks and Systems 391

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Ergonomics for Design and Innovation

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Designing Cannula Cover to Avoid Infections in Central Venous Catheter

Ameya G. Pathak, N. R. Rajhans, and Atul Sajgure

Abstract While treating patient at end stage renal disease (ESRD) or chronic kidney disease (CKD), doctors opt for dialysis or transplant depending on criticality of kidney infection. A thorough study of hemodialysis using central venous catheter has been done in this paper. There is very crude method used to cover ports and limbs of central venous catheter. Due to this, patient faces lots of problems, such as water contact to the body part is to be completely avoided. So, patient cannot take bath and it also obstructs the routine activities. In addition to this, it is also susceptible to infections. Sometimes, body part gets infected through which central venous catheter gets inserted into patients' body. Eventually, it increases complications to doctor while treating the patient. To resolve this issue, a product is developed to cover the port and limbs of catheter so that patient will be able to perform his daily activities with ease. Before finalizing the working prototype, different ideations were tried and tested. Through Human Anatomical study has been done before finalizing the design, so that it can be fitted anywhere on the body. This study provides a feasible solution to problems faced by doctors and patient while using central venous catheter (CVC) during hemodialysis. The current work deals with innovative techniques in the management of ESRD and CKD.

Keywords End Stage Renal Disease (ESRD) · Chronic Kidney Disease (CKD) · Central Venous Catheter (CVC) · Hygiene · Ports · Limbs

1 Introduction

In vertebrates, kidneys are two bean-shaped organs. The kidneys are placed on the left and right sides of the retroperitoneal region. Size of the kidney in adult human

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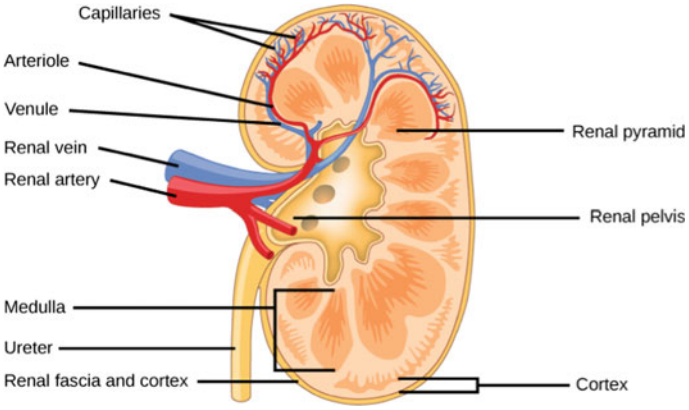

Fig. 1 Basic kidney structure [1]

is around 11 cm [4.3 in] in length. Blood enters through the paired renal arteries and exits through the paired renal veins. Waste materials and excess water are removed from the circulation and transported to the bladder as urine as blood travels through the kidneys. The kidneys also control blood pressure, balance substances such as sodium and potassium, and produce hormones that aid bone growth and blood health by producing new red blood cells (Fig. 1).

1.1 Function

The nephron is the kidney's microscopic structure and functional unit. It filters, reabsorbs, secretes, and excretes the blood it receives; the result of these actions is the creation of urine. Each human adult kidney contains around 1 million nephrons. The kidney's principal function is to produce urine and purify blood. Each kidney filters waste and other compounds that are no longer needed by the body. The kidney's most significant functions are:

- Removal of waste products
- Removal of excess fluid
- Mineral and chemical balance
- Blood pressure control
- Red blood cell synthesis
- Bone health

Humans can usually live properly with just one kidney because they have more working renal tissue than they require to survive. Chronic kidney disease develops only when the amount of functioning renal tissue is severely reduced. Renal replacement therapy, such as dialysis or kidney transplantation, is recommended when the

glomerular filtration rate has dropped to dangerously low levels or when renal failure causes significant symptoms.

2 Literature Survey

2.1 Types of Kidney Disorders

See Fig. 2.

2.1.1 Acute Kidney Injury

This is renal injury that occurs suddenly. It will be temporary in most situations, but it may develop to long-term chronic renal disease in certain people.

- The most prevalent causes to kidney tissue damage are excess medication acute infection or radioactive dye.
- Blockage of urine exiting the kidney [due to kidney stones or an enlarged prostate, for example] [4, 5]

2.1.2 Chronic Kidney Disease [CKD]

Kidney function frequently deteriorates with time. CKD is the medical term for this. It can sometimes lead to ESRD (also known as kidney failure), requiring dialysis or a kidney transplant to stay alive. CKD can be caused by a variety of factors, the most common of which are:

- Kidney blood arteries damaged by excessive blood pressure and diabetes.
- Disease or immune system attacks on kidney tissue [glomerulonephritis].
- Polycystic kidney disease is characterised by the formation of cysts on the kidneys.
- Damage to the kidneys caused by the backward flow of urine [reflux nephropathy].
- Kidney or urinary tract abnormalities that are present at birth [4, 5].

2.1.3 End-Stage Renal Disease [ESRD]

Complete renal failure occurs in this situation, which is frequently caused by chronic kidney disease. Dialysis is required for patients with ESRD to live. Kidney disease can be caused by a variety of factors, and the exact cause isn't always recognized. Some aspects of treatment are universally applicable, regardless of the origin of the condition. However, because kidney disease can have serious consequences, doctors will constantly try to figure out what's causing it [4, 5].

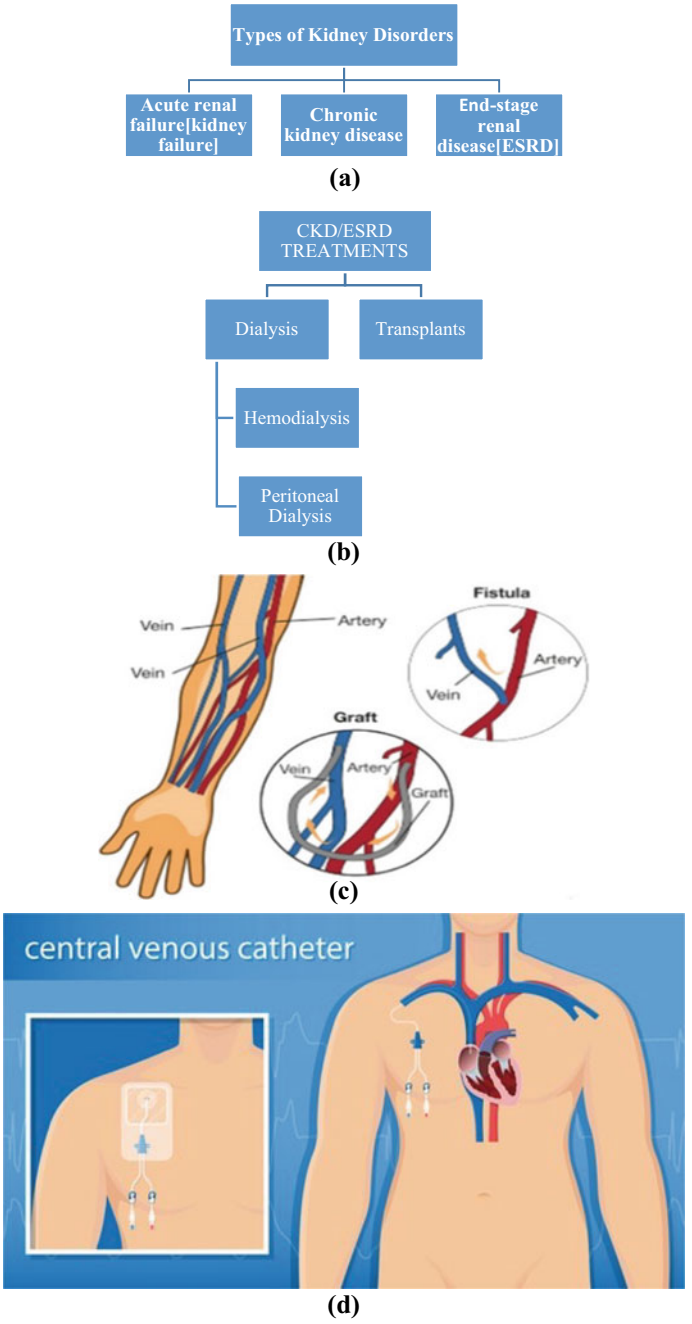

Fig. 2 **a** Types of kidney diseases: a flowchart, **b** Treatments for CKD/ESRD: a flowchart, **c** Vascular access [2], **d** Central venous catheter [3]

2.2 Treatments

2.2.1 Dialysis

CKD and ESRD are treated with Dialysis and Transplant depending upon the severity of the disease. Dialysis is generally carried out in two ways. Hemodialysis and Peritoneal dialysis.

Hemodialysis is a procedure that removes wastes from the blood, restores electrolyte balance in the blood, and removes excess fluid from the body using an artificial membrane (dialyzer). The patient is connected to a filter [dialyzer] through tubes attached to blood arteries for hemodialysis. The doctor surgically establishes a vascular entry, or an entrance point, into the blood arteries to provide blood flow to the prosthetic kidney. The two kinds of vascular access appropriate for long-term dialysis treatments are the arteriovenous [AV] fistula [which links an artery with a vein] and the AV graft [which is a looping tube]. For short-term usage, a catheter can be inserted into a large vein in the neck. [2]

- The number of patients with ESRD is continually increasing, resulting in increased need for hemodialysis [HD]. The optimum way for administering HD was through an arteriovenous fistula [AVF]. For hemodialysis, there are three basic forms of dialysis access.
- **Arteriovenous fistula [AV Fistula]**
- **Arteriovenous graft [AV Graft]**
- **Central venous catheter [CVC]** [6].

For patients who are constantly on the go, peritoneal dialysis can be a good option. Dialysis can be done at home with the help of a PD catheter, and it takes much less time.

2.3 Central Venous Catheter [CVC]:

CVC stands for central venous catheter, which is a flexible, long, plastic y-shaped tube that is threaded through the skin into a major vein in the neck, chest, or groin. Dialysis line [CVC] insertion is the process of inserting a soft plastic tube [twice the length and half the breadth of a pen] through the skin into one of the big veins in the neck or groin near the top of the thigh. The CVC can then be attached to the tubes on the hemodialysis machine, allowing blood to be pumped from the body to the machine and returned to dialysis. A CVC isn't meant to be a long-term access method [2, 6].

CVC is carried out only in case of emergency. A central venous catheter is generally used while waiting for surgery for AV fistula or graft. It is also an option if AV fistula or graft is not feasible. And if vascular access were continuously inserted through same insertion point at the time of dialysis. It is difficult to find veins and

arteries. CVCs are implanted in the x-ray department or the operating room by a nephrologist, surgeon, or radiologist. Once inserted into veins, a central venous catheter can be utilised right away.

3 Methodology

3.1 Human Factor Issues Related Doctors and Patients

As water-contact with vascular access part is restricted, the hygiene is not maintained properly, and in that case chances of infection are high. Patient usually avoids taking precautions. Sometimes they leave the caps open. Normal practice is to stick out white medical bandage around caps of port and limbs so that water contact is avoided. Sometimes bandage used is waterproof while sometimes it is not, so it is effectively creating problems to the patient.

There are products available in market, but they are not user friendly. While using the products, patient's movements are obstructed. In simple words ease of use is not there, that's why patient and doctors avoid those products.

Existing treatments follow basic coating from medical grade adhesive tape cum band aid to the caps of port and limb. Which is still not serving the purpose. Patient still cannot take bath, moreover, sponging is also not possible. Because of which hygiene issue still exists. To tackle this situation, after brainstorming with doctor, major take aways are as follows:

- Facilitate ease to the patient while performing his/her routine activities.
- Maintaining hygiene.
- Compact product which will not hamper dressing.
- Identifying biocompatible material [7].

Personal hygiene is important for both health and social reasons. It entails keeping one's hands and body clean to avoid the transmission of germs and sickness. Personal hygiene enhances one's personal health while also having an impact on the lives of others. It minimizes the chances of body infection because it requires daily body cleaning and self-care. It is necessary to have a daily personal hygiene practice—but in this scenario, it is not possible to carry out daily activity because of CVC.

It is important to maintain the hygiene level near CVC inserted area. If it is not maintained properly there are chances of infection. There are products available in the market to tackle these kinds of problems. But cost and ease of use are two major concerns due to which patient avoids using these products.

Ease of use is a simple notion that measures how simple a finished product is to be used by its intended users. Design is frequently a struggle between delivering usefulness and simplicity of use. It is critical to consider ease of use during the design phase, and to fulfil the need for ease of use where possible [8].

3.2 Design Specification

The average size of cannula that pops out of human body varies from 4 to 8 cm depending on person to person. Diameter of the base depends on dressing area or exit site. Taking into above considerations height of cannula cover was identified as 10 cm and diameter of complete cover as 6 cm [9].

3.3 Material Used

Before finalizing the material to make cannula cover, few materials were shortlisted such as Silicone Rubber, Natural Latex, Polyurethane, AT-10 resin, Polyisoprene. Out of which silicone rubber was finalized. Silicon rubber is selected based on following properties which makes silicone rubber stand out from other in regards with waterproof cannula cover.

- **Biocompatibility**: Liquid silicone rubber [LSR] is odourless and tasteless, and it has proven to be exceptionally compatible with human tissue and bodily fluids. It also inhibits the growth of microorganisms. The FDA, ISO, and Tripartite biocompatibility criteria for medical devices are all met using medical grade silicone.
- **Chemical Resistance**: Water, ammonia, oxidising chemicals, and certain acids are all resistant to silicone.
- **Insulation/Electrical Properties**: Silicones have excellent insulating qualities. Silicone's intrinsic nonconductive properties, as well as its ability to sustain dielectric strength in severe temperatures, outperform latex and other materials.
- **Mechanical Properties**: Tensile strength and elongation are both excellent in LSR. Silicone is also more flexible and has a lower compression set.
- **Thermal Resistance**: Silicone is more stable than other elastomers in the temperature range of -59° to 260°F.
- **Sterilization**: Customers can sterilise their products using a number of techniques, including EtO gas, gamma or E-beam irradiation, and steam autoclaving.
- **Molding Mechanism**: Compression moulding, transfer moulding On LSR, liquid injection moulding (LIM) can be employed.
- **Cost**: When compared to the other materials listed, the price is a little higher [10].

It can withstand temperatures of −59 to 260 °F. Sometimes patients want to take bath from hot water, so the product/cover will not affect by it. It is also highly resistant to weathering, oxidation, and water. Silicone rubber can be immersed in water for long period with water absorption ratio of 1%. Based on all the considerations below are the 4 ideations.

3.4 Ideations

1st ideation was a simple one with hatch locking system. In the design section upper part is different and lower part is different. Two different dies were needed but due to locking mechanism this ideation was discarded. As water may pass through two different parts while bathing.

This ideation also worked on the two-part assembly mechanism, but upper part follows rolling mechanism with adhesive will stick on its bottom. But due to complexity this design was also discarded.

3rd ideation was a single assembly with open top, which is covered by cap like structure. Which partly stick top surface of cannula cover. But this being discarded because of wide opening that may cause water insertion while having bath.

4th ideation was the simplest one with single assembly only, with adhesive being on bottom part only. This will help to keep exit site water intact. With being simplest and effective one this design was finalized.

After finalising 4th ideation, first initial prototype was completed using band aid and normal plastic just to get proper visualisation.

3.5 Advantages of Cannula Cover Over Existing Equipment's

As previously stated, CVCs can emerge from the neck, chest, groin, and other body parts, thus the present product is not universal; it is body part specific. To use them at any part adjustment, need to be done. (As per Fig. 3a, b) Proposed working prototype is easy to mount on any body part as anthropometric data of body is also considered while designing cannula cover. The port and limbs of the CVC are covered, allowing patients to bathe or mop while in the hospital. Which also help in maintaining hygiene and reducing infection issues. Because the material utilised is silicone rubber, which is naturally soft and smooth, the cannula cover will not tangle with clothing. The product is simple to use and take off. The proposed solution is extremely effective at resolving all human factor issues that emerge when utilising current products.

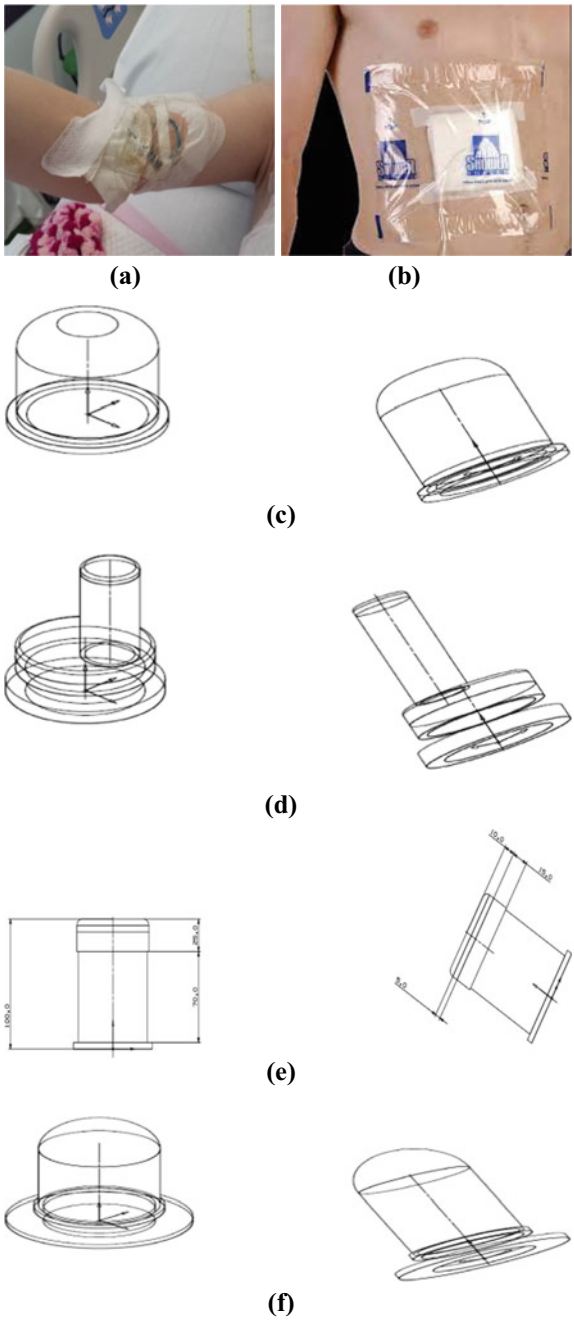

Fig. 3 **a** Ports and Limbs covered by Bandage, **b** Central Venous Catheter covered by bulky waterproof cover, **c** Ideation 1, **d** Ideation 2, **e** Ideation 3, **f** Ideation 4, **g** Final working prototype

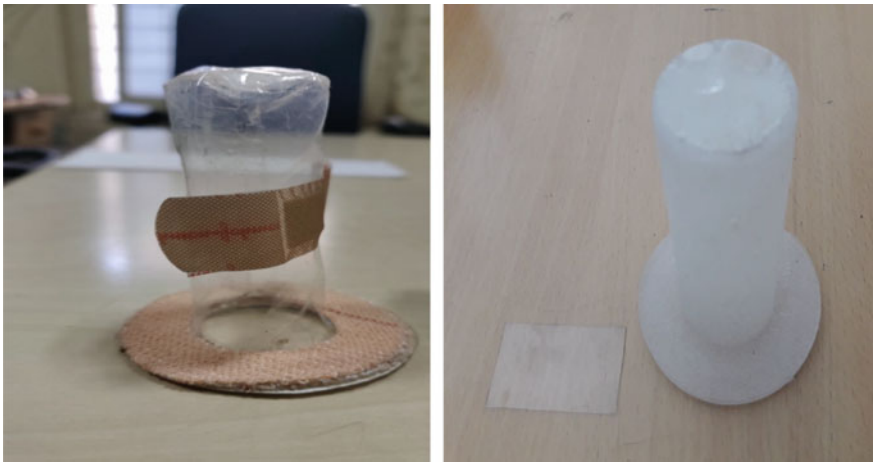

Fig. 3 (continued)

4 Conclusion

Final working prototype is developed and is being provided to the patient with all safety precautions for trail purpose. It is easy to use. It is to be sticked on the skin similar to band aid. Patients were satisfied with the product. All the problems associated with central venous catheter were addressed using waterproof cannula cover. As cannula cover is completely waterproof, patient can take bath. With the help of this hygiene problem is also solved. Cost is also affordable. It can be changed as per the requirement. No need to go to doctor for covering canula. Product is reviewed and recommended by doctors.

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Redesigning the Basket Support for the Tea Plantation Workers—Occupational Safety and Health Design

Tanya Prasad

Abstract The purpose of the project was to study through design on the ergonomics of the tea leaves plucking workers in hilly terrain and to find a suitable design intervention to reduce their load and improve their ergonomic conditions. The situation was studied from a design perspective to understand their movements and actions throughout the day, including the loading and unloading of the basket. The study uses User interviews, a Guided tours, day-in life, and role play as the research tools. Having been worked in terrains of changing angles, the workers in tea plantations still continue to use the traditional make-shift design of carrying the plucked leaves on their heads in baskets. Weighing approximately up to 30–40 kg, these workers navigate through the thick shrubs of the tea plantation balancing the entire weight on their head throughout the day. From an ergonomic point of view, the standards were studied and compared with the real situation to emerge with the most optimal solution. A simple and replicable design solution was suggested to help carry the basket with the least interference to their number of steps-in-action or their existing resources. Special consideration was kept to make the design easily replicable with locally available materials and cost-cutting. Designers and design researchers can use these findings as a foundation for an ergonomic change in the design of the basket as a means to develop a healthy work environment, reduce occupational hazards, increase productivity and improve the work-life of the workers.

Keywords Occupational health · Ergonomics · Local design

1 Introduction

Tea Plantation in India is one of the major contributors to the economy of our country. India is the second largest producer and the fourth largest exporter of tea in the world. Tea industry is the second largest agro-industry in India. Tea production in India was 1322 million kg in 2017, which is about 23% of the tea production in the world [1]. With a workforce of a million people, half of which are women, it is one of the

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largest employment sector. Our major economy depends on the production of tea, which is a high labour intensive work. From the nursery development to plucking and packaging at the end, high man labour is needed at every step of the process [2]. Tea plantations are mainly located in rural hills and backward areas of Northeast India and Southern Parts of India [3].

Ergonomics plays a crucial role in the productivity and the lives of the workers in such labour intensive jobs. According to Occupational Safety and Health Administration, Ergonomics is applied science of equipment design (for the workplace) intended to maximize productivity by reducing the operator's fatigue and discomfort. Ergonomics is the science of fitting jobs to people. Ergonomics encompasses the body of knowledge about physical abilities and limitations as well as other human characteristics that are relevant to the job design. Ergonomics is the application of this body of knowledge to design of the workplace [4]. Good ergonomic design makes the most efficient use of worker's capabilities. When defined in terms of science, ergonomics is the science of designing products that work in accordance with the way humans think, see and behave. Products that are compatible with people will dramatically reduce human error, fatigue, discomfort and stress and have a profound positive impact on overall end-user performance [5, 6]. Occupational stress and hazard lead to a clear decrease in productivity due to regular absenteeism, and affects the overall work due to loss of daily work, paid sickness benefits and compensations [7].

The Tea Industry is one of the largest employers of women amongst organized industries in India. Women constitute nearly 51% of the total workforce in Assam. Many of the activities, especially the plucking activity (40% of the total cost of production of tea leaves) performed by the workers in tea plantation demand a high degree of physical effort because of repetitiveness and assuming static awkward posture, leading to early fatigue and work related musculoskeletal problems [8]. In tea plantation industry, the workers are mostly paid on the amount of tea leaves plucked by them. The more quantity of leaves plucked, the more they get paid. Plucking tea leaves requires high level of physical effort which involves continuous static posture with dynamic switched tilting of the body, repetitive movement of hands, continuous gripping and extended reaching. It was observed that in plucking of tea leaves, the workers performed the operation in standing posture with slight bending near neck and low back [9]. This leads to high posture load due to constraints of work and working environment. A continuous exposure to such a working condition leads to occupational diseases such as body pains, pain in the lumbar region, neck and arms, with Musculoskeletal disorder being one of the most evident. This prolonged drudgery work affects the health and has a direct impact on the production and involvement in the work. It can be observed that one of the major factors contributing to this health issues are the inappropriately design tools and work equipment used for such back- breaking and tedious task.

2 Objective

This research tries to study the ergonomic factors that affect the lives of the tea plantation workers in their plucking activity and suggest design interventions that could improve their occupational health and hence overall productivity and lifestyle. The study focuses on the ergonomic aspect of tea plucking from the point of view of their direct effect on the health, occupational stress, work related issues, all leading to the effect on their productivity and overall life. The objective of this study is to come up with an easily adaptable and incorporable design that can be replicated without any additional pressure on expense. The materials and design would have to be ideally localised and manufactured by the workers themselves if needed. These above mentioned factors are the novelty of the study and design interventions which sets it apart from the other designs proposed.

3 Research Methodology

The research methodology involves primary data collection using field study, direct semi-structured interviews and personal interactions, understanding of the context and stakeholders. Questionnaires and live interactions were conducted with the workers in a contextual format. The data was collected on field by the researcher. The use of both tools helped in understanding the objective as well as the users overall aspects of lifestyle. A total of 5 workers, from ages 22–45 years, were involved in direct interviews as part of the study. They belonged to a lower economical range with daily wages income. The sample size forms the weaker dimension of the research study conducted. Visual data in forms of photos and videos was also captures as part of the primary study to locate the minute details in their activity. Role playing was also used as a tool to give a better understanding of their interaction with the basket and the movements involved in the process.

Secondary data involved literature study done to understand the existing work, collection of data, comparison and benchmarking of solutions around in this field. The approach also derived the 5 W and H (What, Where, Why, When, Who and How) of the study and active relevance in the current scenario. Journey mapping, Context study, Mind Maps were used as some of the tools to assist the study and get a better understanding to draw insights and inferences.

4 Context

4.1 Cultural Aspect

The study was conducted in the tea plantations workers around Wayanad in Kerala. Tea plantation in the hilly terrains of Kerala has a high number of unorganized labor. The terrains of Wayanad in Kerala make it a good choice for plantation of tea, coffee and spices due to the weather conditions and rain received. Even with a strong Labor Union to support the unorganized workers, the workers still find it difficult to lead a lifestyle that balances their work-home and health.

The tea plantation industry is still a women dominated industry. Women play a pivotal role as field workers in tea estates. Majority of workforce in plucking operation are women. There are more than one million workers in the tea industry in India comprising mainly of scheduled castes, tribes and ethnic minorities of which more than 50% are women [10]. With high labor hours, low wages, poor sanitation, poor medical facilities, and an exploitative management, these workers, especially women are left malnourished and vulnerable to the consequences of the unhealthy working conditions. Added to this is their dual pressure of performing the daily household chores. Women workers suffer from work related health problems because neither the tasks nor the equipment they use, which are normally designed for men are adapted to their built and physiology [11].

4.2 Working Conditions

In a study on the occupational health hazards and safety measures conducted on the tea plantation workers of Kerala, it was revealed that the workers in tea garden have to work for 41–50 h per week [12]. They work for 6 days a week for 7–9 h each. Working in an exposed condition under the sun, the water breaks usually take 10 min in the common points. But due to the walk to these points with the basket, it is usually postponed till the common collective lunch break which is for an hour. To also reduce the weight of the materials they carry, they are not inclined to carry water bottles with them while plucking the tea leaves.

The baskets used are usually bamboo with a strap made of cloth that runs across the basket while the other end is balanced on the head supported by a coiled piece of cloth. The use of gloves are not seen due to the effect on the speed, gripping strength and inconvenience in plucking. The empty basket weighs about 2–3 kg alone. The workers work in three shifts with 10–15 kg at each load. At the end of the day the total weight of the basket amount to around 25–30 kg that is carried to the collection point.

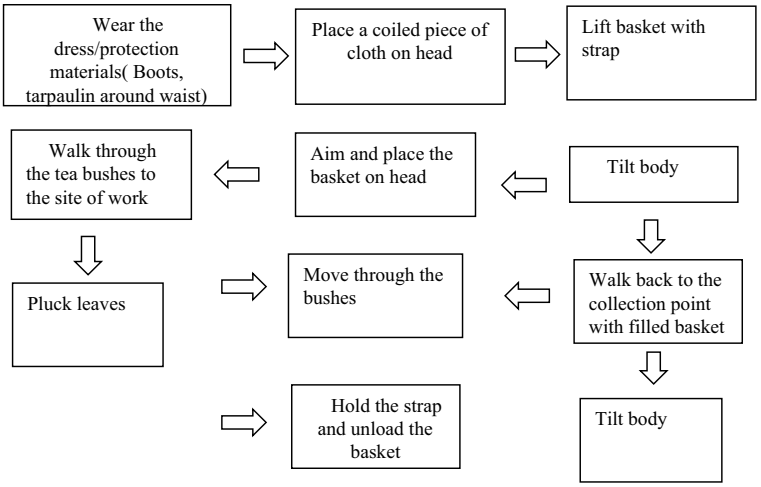

Fig. 1 Journey mapping of tea plucking process

The work conditions also exposes them to constant humidity and dampness in the plantation making them prone to leech attacks that suck blood on their legs. Navigating through the rough and tightly packed tea plants also leaves them with scratches, cuts and bruises from the sharp and sturdy stems of the tea branches. To prevent these they are forced to wear knee length rubber boots wrapping their legs in salt solutions spread on their legs. These affect the skin conditions, continuous exposure and retention to dampness or sweat and difficulty in walking due to lack of perfect sizes rubber boots that may fall off, often resorting to stuffing the larger boots with cloths or dragging them while they walk. They also practise tying a rough piece of cloth/tarpaulin around their waist to prevent the bruises from the tea branchers when they have to lean in to reach the end leaves.

The Journey Mapping of the workers was traced as (Fig. 1):

The process flow of the activity(Tea plucking) was mapped as follows (Fig. 2):

5 Existing Practices and Why

There were found to be different ways of wearing the basket (Fig. 3). The primary research showed hanging of a plastic weaves bag on the head with a cloth strap under layers of cloth piece placed on the head. Secondary research showed the additional possibilities of wearing it across the shoulder with one strap, wearing it on one shoulder with one strap, running the strap through the side of the basket and running the strap though the bottom of the basket (Fig. 4).

The use of machines or automated mechanism wasn't seen to be practised as part of the cost cutting strategy by the administration.

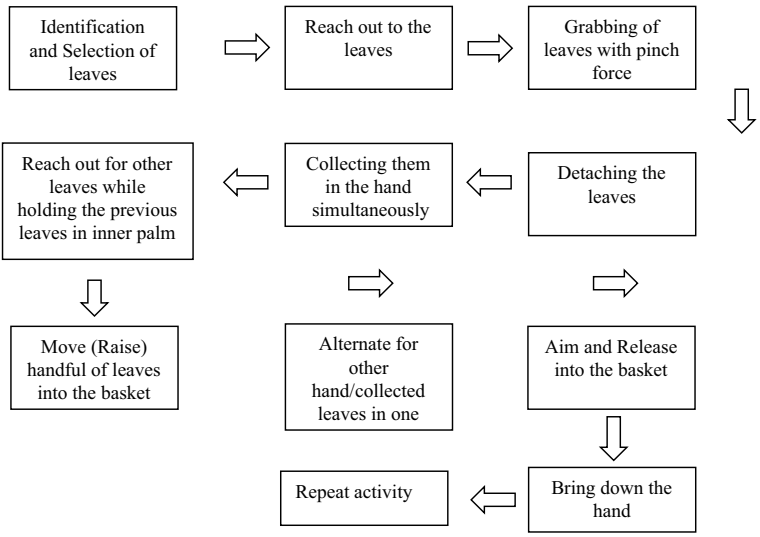

Fig. 2 Process flow mapping

Fig. 3 Image showing the worker during the process

The main materials used for the tea plucking activity were identified (Fig. 5). Some of them are listed as follows:

1. Basket/Big Plastic bag/Cloth bag—The bags were preferred to have enough airflows and ventilation. These help in maintaining the tea leaves at the bottom of the basket and prevents them from being crushed or squeezed under the weight.
2. Strap—Either attached to the bag in case of the plastic or cloth bag or added externally for the bamboo basket. The strap was usually attached so as to give a lower grip to the basket. It has broad width to avoid cutting or add pressure to the skin.
3. Clothes—Usually folded or rolled and coiled—These acted as the shock absorbers of the weight. They were the cushion on which the strap was placed. These clothes also gave slight shade from the sun.

Fig. 4 Images showing alternative ways of wearing the basket [13]

Fig. 5 Materials used during the process

4. Cap/Hat (Plastic or Bamboo)—these were used in slight drizzle or in extreme sun. But the use of these is preferred to be avoided since it restricted the degree of freedom in the movement of the head
5. Thick Cloth/Tarpaulin piece—Tied around their waist to prevent them from the scratched and bruises of the thick tea branches.
6. Boots/Slipper—Rarely seen—These were rarely used since most laborers could not afford them on their own while the profit-driven administration try their best to cut down on the supplies. Cloth dipped in salt solution was used by most to prevent from leech attacks in the plantation.

Fig. 6 Role playing activity

7. Full sleeves were worn by most to prevent their hands from bruises from the thick branches while plucking. The shirts used by women were usually shirts worn and discarded by the men.

A main factor that can be highlighted as part of this study was the high use of local materials. Most of the thing were fixed, repaired or maintained by the labors themselves and new products were only bought under absolute need. The support strap, the cloth on their head, the cloth tied around their waist were all made themselves out of the materials found by them, and signs of repairs and work to maintain it were clearly visible.

It was observed that the basket was preferred to be balanced on the head due to the following main reasons (Fig. 6):

1. It gave a good grip on the head and stability to the whole basket alignment.
2. It was easier to navigate and locate the basket. Often it was found that the basket was slightly swayed to either sides for putting the tea leaves in. Having the basket balanced in the head made it easier to aim and access it.
3. The activity of tea plucking involved stretched reaching to the end of the bushes, for which it was much easier if the arms and shoulders were free. Having a strap that runs across your shoulders was seen restricting to the arms and shoulder movement and an reason to reduced speed of action.
4. Uniform distribution of load. Balancing the basket on the head distributed the load evenly to the whole body.

6 Design Intervention

6.1 Design Aspects

Focus and attention were given to two main factors:

1. The material: The design should not be dependent on the material, as sourcing it and repairing it would act as an additional obstacle to its implementation. The material should be able to be sources locally
2. The process: The design should not hinder the existing process or have a drastic change to their current methods of tea plucking. This would ensure that an additional training would not be required and can easily be adapted into their current methods.
3. Ease of use: The product should be easy to make, use, carry around and store. This would encourage the labours to use it more and be naturally inclined to promote it too.

6.2 Design

Based on the anthropometric measurements and analyses, ideations were done and an improved additional support strap was designed. Figure 7 shows the proposed design of the addition strap. The design suggested an additional support that can be worn in addition to the existing basket and straps. This strap need to be worn only once and works independent to the basket. This helps in preventing any additional cognitive steps while repeated loading and unloading of the baskets throughout the

Fig. 7 Suggested design of the additional support strap

Fig. 8 Side view image showing details of the additional support strap with basket

day. The design includes a single long strap that is worn a across the body to give maximum distributed support. The strap consists of two pieces that are joined with a normal buckle. The length of lower section of the strap can be adjusted even after wearing it. The top piece of the strap has an additional neck support that gives it a cushioning effect while the bottom part has a double strap with two sections to support the basket from below and side (Fig. 8).

Though the additional features give it an extra feature and ergonomic support, the strap could also be easily made by the users with locally sourced materials. The design focuses on the method of wearing it than the materials. The is the novel factor of the design. The single strap that is worn across the body helps in distributing the load more evenly across the shoulder and back. While the ease of design that frees the hands to be moved around with good degrees of freedom ensures that the stap doesn't act as a hindrance to tea plucking.

An additional strap worn once in a day without causing any hindrance to the existing practise gives an additional support for the heavy basket from the bottom and distributes the weight evenly across both the shoulders in addition to the support on the head. This leaves their hand free and available for picking and throwing leaves while their basket remains the same.

The design and its features have been shown in the renderings below (Fig. 9):

6.3 Design Dimension

The Design is novel in the fact that it has the flexibility of the dimension. However, a basic dimension has been followed for good ergonomic accommodation of the workers body (Fig. 10).

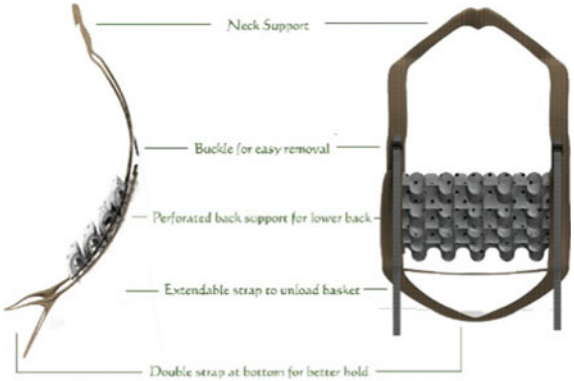

Fig. 9 Image showing details of the additional support strap

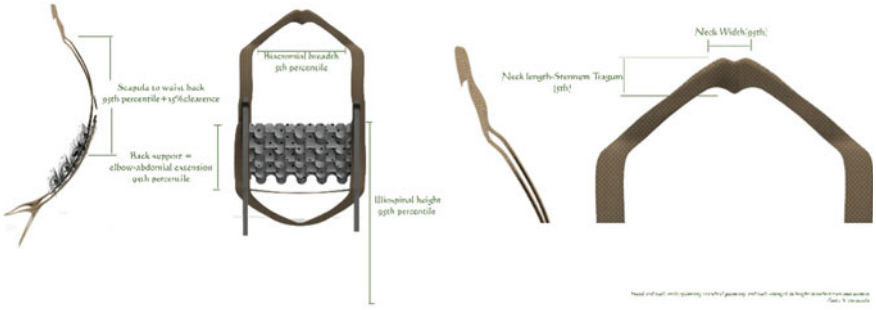

Fig. 10 Image showing dimensions of design

7 Conclusion

The study concludes that the factors affecting the occupational health of the workers in tea plantation are multi-layered and hence complex in their nature for implementation. Even with advanced studies conducted and ample deign interventions suggested, one could still see the absence of their implementation on ground level. Factors such as communal aspects, labour rules, cost cutting techniques by the administration, demand–supply rate of tea, and the traditional cultural history of the place add on as the hidden layers making the most prominent reason invisible in the face of the observer.

However this design intervention, keeps in mind the economical constraints and the obstacle of having a middle person and empowers the workers to themselves take the needed measure to improve their lives and health.

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Design of Personal Protective Wear for Disabled People: An Improvisation on Ergonomics

Surya Bharath and G. Mohamed Zakriya

Abstract Post-pandemic the need for inclusive design in personal protective wear was essential to accommodate people of various disabilities. The implementation of universal design will help us reach versatile and flexible outcomes. The designs will be an explosion to create an inclusive society. Universal design aims at the inclusivity of the entire society and is designed to minimize the number of people excluded from using a design. The paper seeks solutions to support and facilitate as possible, to assist people to achieve their utilitarian and ergonomic goals through universal design for personal protective wear. The analysis is done on its ergonomics, aesthetics, and utility factors. The paper proposes solutions based on universal design principles by analyzing constraints in using regular personal protective wear. The proposed design solution aims to achieve the ergonomic and aesthetic factors of personal protective wear for differently-abled.

Graphical Abstract

Keywords Universal design · Personal protective wear · Ergonomics · Disability

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1 Introduction

A condition of body or mind which makes a person more challenging to do a certain activity or interact with the world is defined as a disability. People with disabilities are not the same, as the huge population has varied intensity and category of disability. Designing personal protective wear for the disabled is a crucial process as the clothing should not pose an extra physical barrier to them in their actions. The health pandemic across the globe has caused a huge demand for personal protective wear, of which the differently-abled are excluded from having an ergonomically fit PPE (Personal Protective Equipment). They require special clothing design to fulfil their needs and ergonomically accommodate themselves. The paper will analyse the ergonomic issues associated with using the existing personal protective wear and suggest few design enhancements. Using universal design we will able to bring in unique and holistic design solutions in personal protective wear which will improve accessibility, comfort, aesthetics, and ergonomically advanced clothing.

1.1 Disability (Statistics) and Universal Design for Inclusivity

This section will focus on the disabled population of India and also compare the population with various state populations. And will correlate how the universal design principle will help improve the design and bring inclusivity in personal protective wear.

1.2 Disability

As per the International Classification of Functioning, Disability, and Health (ICF), disability and functioning are related to body functions and structures, activities, participation, and environmental factors. It states that the level of functioning is an individual's ability of dynamic interaction with the health, environment, and personal factors as it is bio-psychosocial [1]. This made us better understand and categorize the disability in an individual. The model of disability which is multi-dimensional and interactive is illustrated in Fig. 1, which draws the factors influencing disability such as personal and environmental (Fig. 1).

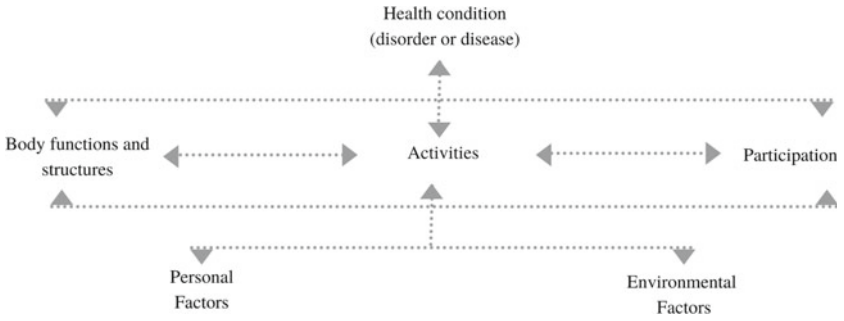
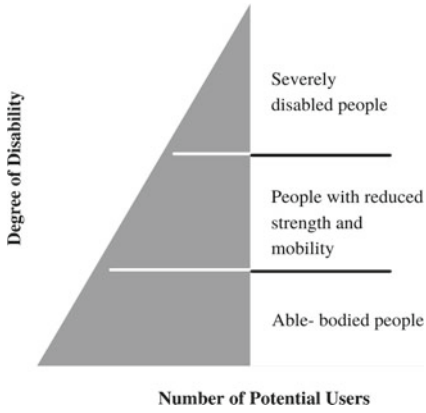


Fig. 1 Disability, Functioning and Health as per International Classification (Adapted from reference 1)

Fig. 2 The user pyramid model (Adapted from Reference 2)



1.3 Universal Design and Inclusivity

The universal design focuses on a design solution for products, systems, and environments that facilitate maximum population and reduce the number of people being excluded. The fundamental aim is to enhance the ergonomic and aesthetic goals through the design principles of Universal design [2].

The usability and accessibility of a product can be maximized as the user base is as potent as possible. A well-equipped design principle that enhances the design features and satisfies the design requirements of the disabled. Working on the impairment level of the people with varied diversity, in consideration with the skill level, demographic profile, and suitable ideation approach the universal design will build inclusivity for the society [3].

The study about Inclusive design made the authors come up with a unique info graph. The cubes represent user competence and the population sizes which allows the designers to visualize and reflect the consumer needs effectively. In practicality, there has to be a rigorous understanding and interpretation of the problems to produce

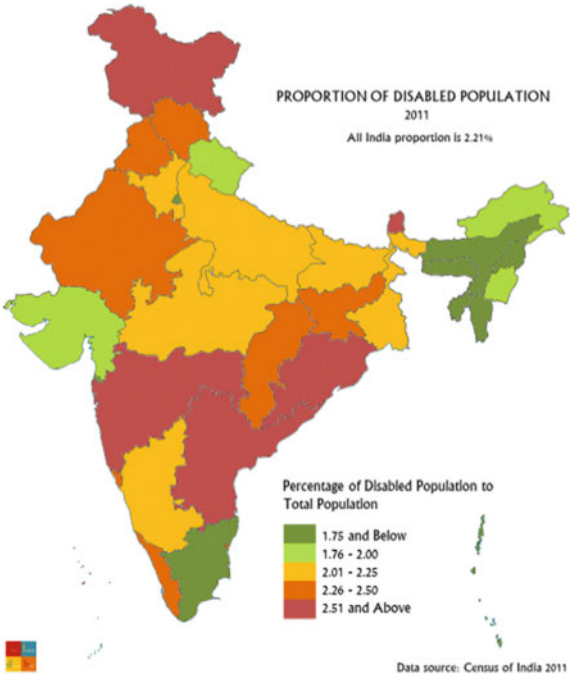


Fig. 3 Disabled population of India as per the senses 2011 (Adapted from Reference 3)

a product of high accessibility and usability. For a user-centred interface, the design has to be modified and refined by design practices and usability evaluations [4].

2 Design Requirements and Approach

This section of the paper will compare and consolidate the various ergonomic issues associated with personal protective wear from different studies carried out in the field. The review will be on the disability and its associated constraints. And the application of universal design principles for a better personal protective wear design according to the prescribed standards can be achieved.

2.1 Constrains of Disabled People

As per the ICF, the disability is multidimensional which requires thorough study to provide a more viable solution to satisfy all the needs. Figure 1 illustrates that environmental and personal factors influence one's disability.

The enabler Fig. 4 adopted helps us in understanding the limitations of the disabled people associated with the body parts. The thorough analysis of the figure and the

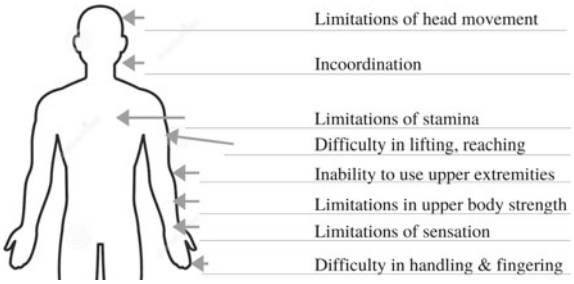


Fig. 4 The enabler figure. *Source* Adapted from Mueller (1996, p. 107)

Table 1 Constrains of disability and the influencing factors

Body roles	*Body structures*
The functioning of the cells, are essential for physiological routine of the body The ICF classifies various components of the body sections such as sensory, mental, pain, voice, and speech which are basic to one functioning. Which also includes cardiovascular, immunological, and digestive metabolism. Further on movement and skin-related functions	**The body structures are the anatomical parts of the body that forms the basic framework of humans such as organs, limbs, and their components** The Structure of the nervous system, eye, ear, speech, as well as the structure of voice, speech plays a crucial part in defining the body structure. Various system structures such as the digestive, cardiovascular and metabolic structures are analyzed for a disability
Activity and Participation	*Environmental factors*
As an individual how he executes a task and acts in a life situation The individual must be able to apply the learning and knowledge to solve various tasks and demands, to communicate his thoughts. For a better social and civic life the interpersonal interactions are essential	**In a social environment, the physical and social interactions act as barriers or enhancers to conduct their life** Social life is influenced by humans as well as technology which includes human-made changes and supports the relationship and systems

Adapted from ICF overview, Pg. 5

associated factors helped us in bring out the most suitable solutions as per the requirements and needs. The major parameters of functioning and disability set out by ICF include body function, body structure, impairment, participation restriction which are set out in detail in Table 1. The table discusses the factors and body disabilities associated with it. As per the ICF framework and its classification system, various tools for accessing an individual functioning are mapped to give a generic score based on the disability extent an individual has undergone. The disability poses an extra burden as a wearer and user of the clothing. The scores are uniform and generic scales to record the problem for assessing the extent of disability. The ICF scoring scales are as charted in Table 2.

Ergonomic Solutions for Disabled Personal Protective Wear

Based on the five key aspects of ergonomics safety, comfort, ease of use, performance, and aesthetics the various design suggestions have been arrived at for accommodating varied populations with distinct disabilities [5]. These aspects helped in understanding the user requirements and provide an efficient solution for the issue that caused hindrance to the wearer. Ergonomically oriented safety of Personal protective wear design is essential to accommodate the different physical anatomy of the wearer, as their movements are restricted due to some sort of disability. The design will reduce the physical constrain and allow border ease of movement, enhancing the comfort of the wearer. The sole idea of the design is to improve the functionality of the personal protective wear, where the disabled person does not stress harder to do a particular action providing freedom from pain [6]. The design suggestions are consolidated in the Table 3. The designs are also produced meeting the universal

Table 2 Generic qualifier scores as per ICF Framework (Adapted from ICF overview, Pg. 7)

Generic qualifier:	Qualifier for Environmental factors:	
0 No difficulty	0 No obstacle	+0 No assistance
1 Difficulty—Mild	1 Obstacle—Mild	+1 Assistance—Mild
2 Difficulty—Moderate	2 Obstacle—Moderate	+2 Assistance—Moderate
3 Difficulty—Severe	3 Obstacle—Severe	+3 Assistance—Extensive
4 Difficulty—Major	4 Obstacle—Complete	+4 Assistance—Complete
8 No major difficulty	8 Obstacle not specified	+8 Assistance not specified
9 Irrelevant	9 Irrelevant	+9 Irrelevant

Table 3 Ergonomic design solutions of personal protective clothing for the disabled

	Design problem	Design approach	Target design attribute	Universal design principle achieved	Expected technical points
Hands and elbows Stress in any of the action - Lifting, getting or transport of things Inability in using upper extremities Restrictions of sense Restrictions in upper body movement	Improvisation on mobility	Replacement of seams from uncomfortable locations, Placing the seams at elbows and armhole above the actual line, with increased ease for better movement	Functional	Equitable use Low physical effort	2250

(continued)

Table 3 (continued)

	Design problem	Design approach	Target design attribute	Universal design principle achieved	Expected technical points
Whole-body The upper body motion is challenging Stress in any of the	Enhanced physiological benefit	Added pouches & pockets with large opening and secured mouth. This will allow the wearer to keep the personal belongings and provide the required room for storage	Functional	Equitable use Simple and intuitive usage	2250
Hands and elbows Incapability to use the upper extremities Confines of sensation Limitations in upper body strength	Ease of treatment	Detachable sleeve, as the examination, can be done without any physical efforts	Functional	Regular and in-built usage Less physical action Noticeable information	2250
Chest and Legs Range of restriction in the upper body movement Inability to use lower extremities	Increased accommodation of various body shapes and sizes for inclusivity	Variable chest and hip sizes with drawstrings and Velcro, so that various deformities in thse body can be accommodated	Functional	Flexible in use Size and space for approach and use	2250
Whole-body	Increased wearer modesty	The front garments with the front opening will help the wearer to maintain their dignity. In case of any malfunction, they can identify and rectify it	Eloquent	Simple and intuitive usage Perceptible information Low physical effort	2504

(continued)

Table 3 (continued)

	Design problem	Design approach	Target design attribute	Universal design principle achieved	Expected technical points
Whole-body	Enhanced social dignity of the wearer	Improved pattern choice and better fabric colours to make them feel better	Eloquent	Equitable use	2504
Whole-body	Use of gender-neutral fabric colours and pastel shades	The use of neutral shades of colours and patterns will make them feel better	Aesthetic	Equitable use Flexibility in use	83

design principles discussed in Sect. 3.2. The value for the ergonomic attributes is presented as per the study (Fig. 5).

3 Discussions

3.1 Evaluation of Personal Protective Wear—Standard Testing Methods

The ANSI/AAMI: PB7073 standard- The barrier effect of the personal protective wear includes four standard tests to evaluate the barrier effectiveness (including isolation gowns and surgical gowns). The various test analysis are as stated below:

Impact Penetration Test measures the ability of the materials to resist the permeation of water by spray impact (at 1 psi). The lower the value the higher is the resistance [7].

Hydrostatic Pressure Test, deals with the ability of the materials to repel the penetration of water under raising hydrostatic pressure increasing constantly (0.25–2.0 psi), valued as hydrostatic resistance (cm). The higher the value more is the resistance [8].

Synthetic blood penetration resistance evaluates the ability of the fabric to resist the penetration of blood under the standard environment of continuous liquid contact, which is done only for the surgical gowns. It is either pass or fails [9].

Bloodborne pathogens penetration resistance, the ability of the fabric to resist the penetration of bloodborne pathogens of protective clothing [10].

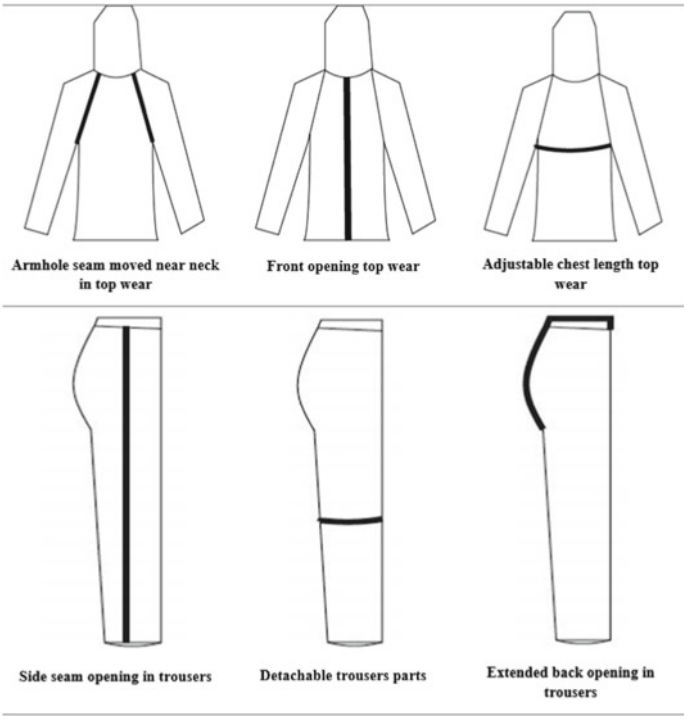


Fig. 5 Ergonomic design solutions for Personal Protective Wear

3.2 Advancements in Personal Protective Wear

3.2.1 Sustainable Personal Protective Wear

This unprecedented pandemic has caused in the rise of consumption of medical wear which in turn has raised the extensive consumption of disposable personal protective clothing. Which has raised the amount of medical waste being generated due to the use of plastic-based materials ad masks, which results in heavy plastic. The research in the area of medical waste revealed that millions of people around the globe will be drastically impacted due to the ongoing plastic medical usage pollution [11]. These studies have paved a new path for designers to focus on eco-friendly protective clothing for a sustainable society using the latest technologies. Incorporating waste sterilization methods and the use of washable and reusable alternatives such as recycled polymers & biodegradable polymers (e.g. rPET, polylactic acid) for production of protective clothing will help in creating a safe and green functional wear [12].

3.2.2 Smart Personal Protective Wear

Wearable technology will pave way for better and efficient analysis of the ergonomics of the personal protective clothing for the wearer. In addition to the protection of the wearer, continuous monitoring of biometrics such as heart rate, body temperature, and respiration are highly valuable for an individual's data using IoT solutions will generate new insights into human health acting as built-in intelligence. Hardware and software integrated monitoring solutions using flexible sensor-equipped wearable's will have high efficiency and comfort for the wearer.

Adoption of smart textiles with technologically enhanced properties known as smart textiles when applied to the garment overalls can sense the change in surroundings and the object which is hot [13]. He latest advances in the field of miniaturized sensors, when applied to personal protective clothing, will incorporate signalization systems and also augmented reality modules for providing better guidance to the disabled [14]. This feature will reduce the unnecessary regular accidents happening for disabled people in their daily life. Moreover, the IoT advancements as stated above will improve the analytical services providing real-time data of an individual. This will also allow data transfer and data sensing simpler. Using printed circuits in the textile will reduce the discomfort and stiffness caused due to the traditional circuits and simplify the use of electronically amplified garments. Which can improve the ergonomics and usability. The use of Bluetooth technology will reduce the weight of personal protective wear and improve the exchange of real-time information [15].

4 Conclusion

The world is composed of people with unique abilities and disabilities, which requires special care to accommodate the personal protective. The solutions proposed in the paper using universal design principles help us accommodate and solve the ergonomic requirements of people with disabilities, as it unifies the needs providing variable solutions. The quality and utility of the personal protective wear for disabled people are enriched in the design solutions.

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Optimal Design of Customized Ankle Foot Orthosis for Drop Foot Patients

Rohit Kumar, Rajesh Kumar, Parveen Kalra, and Rajesh Madan

Abstract Orthotics and prosthetics are components used to support weakened part of the body or muscles which are unable to do its intended function. While earlier one enhances limb ability, later one completely replaces the limb. Starting from Mesopotamian civilization till now, Ankle Foot Orthosis (AFO) had undergoes transition in design development from passive to active AFO and in fabrication process from conventional casting process to Additive Manufacturing (AM) but certain gaps remain unfilled to have an optimality in strength and stiffness. This article comprehensively discusses about "Customization of AFO" fabricated from AM for Drop Foot (DF) patient eccentric requirements in gait stability and energy absorption. Additionally, the scope for low-cost host material and their efficacy on compensatory mechanism for appropriate Gait is provided.

Keywords Customized ankle foot orthosis · Additive manufacturing · Optimal design · Drop foot

1 Introduction

Muscles, Bones, Tendons, and Ligaments play crucial role in carrying out activity in humans, any hindrance or weakness in their co-ordination working or feebleness in them can cause temporary or permanent damage to these vital parts. Orthosis and prosthetics are devices used to support the weakened part of body that unable to function on its proposed capacities. While earlier one enhances limb ability later one completely replaces the limb. In this regard, DF is a syndrome that involves disability in lifting front part of foot and makes dragging of toe on the ground under its own weight [1–3].

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Some causes of DF are nerve injury, muscle dystrophy, spinal disorder, from birth etc. [1, 4–6]. A study conducted by World health organization states 15 million of patient worldwide every year have a stroke which can cause DF in earlier or later stages of life. Structural rehabilitation in lower extremities originated from earlier Mesopotamian civilization. Its first written evidence can be found in Indian text Sushrutra Samhita, a Sanskrit text on Medicine and surgery. Chronological studies overview about material and design aspect of AFO is shown Fig. 1.This figure shows various stages during AFO development process. A boom in AFO research and manufacturing can be seen from 1960s to 2005 due to development in medical science and industrial revolution in many parts of world after than studies is focused on parameters like low weight to strength ratio, economical, perforated design for air circulation, don and doff adaption, low energy expenditure in gait. But these parameters could not able to improve gait pattern as theoretically it is expected. AFO are support devices to assist foot movement while walking. AFO undergo transition in process of fabrication from manual to automation and in fabrication host material from wood to carbon fiber composites and recently natural fiber composite materials.

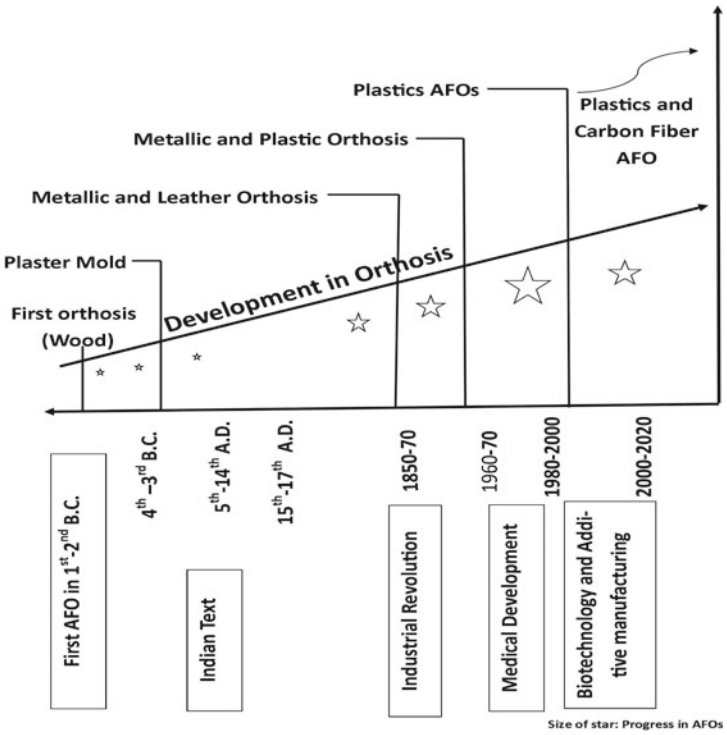

Fig. 1 Stages in AFO development

1.1 Drop Foot and Normal Foot Physiology

Human gait analysis involves study of human locomotors patterns and motion. Normally, one periodic gait cycle is divided in to stance (60% of gait cycle) and swing phase (40% of gait cycle) while stance phase represents time period when foot is on the ground and swing phase when it is in air [4–7]. Stance phase involved initial contact, loading response mid stance and terminal stance while later involved pre-swing mid swing and terminal swing. Main cause of DF is due to weakness of tibialis anterior (TA) muscle. This weakness can be explained on the basis of a circuitry process that starts from top (brain) and moves down (to lower extremities). Walking enables brain cells activation and generates impulses moving from spinal cord to lumber vertebra 4 and 5. Through connection between nerve fibers and sacral plexus, it passes impulse backward through sciatic notch and transmits in to priformis muscle and later this signals passes to down leg sciatic nerve. Sciatic nerve divides in to peroneal and tibial division and peroneal nerve further divide and connects above knee forming common peroneal nerve (CPN). Common peroneal nerve sends signals to TA muscles which pull and contract with tendons on the bones. This circuitry process is fast and any issue in the process can cause DF [5, 6, 8]. In a healthy gait, maintaining forward momentum, stabilization and ground reaction forces are integral part of healthy gait. Momentum provided by arc of motion and pivotal system between heel and its forefoot joints, these joints act as universal coupling mechanism. Initial stabilization can be provided by Initial contact and loading response. Hip provides trunk stabilization and limb control through its movement flexion and extension [9]. GRF provided by body at center of mass (COM), varies with speed of walking, acceleration and position of COM and its magnitude is highest in Heel Contact (HC) and push off phase therefore energy need at this point is maximum in gait cycle [9–11]. Therefore, foot fulfills Kinetic and Kinematic requirement of body in expense of energy requirement.

However, Foot movement in DF is different, instead of normal Initial heel strike in DF, front part rests on the ground or making toes plantarflexion (PL) more in sagittal plane due to weakness and lack of Achilles tendon force [6]. In swing phase, PL angle increases more in initial swing making front part strike prior to heel in terminal swing phase as shown in Fig. 2. Patients suffering DF can experiences more gait abnormality like increase in hip flexion, energy cost, limb damage and joint angle between talus and calcaneus [7, 8, 11, 12].

1.2 Ankle Foot Orthosis (AFO)

One of the methods for controlled foot motion is AFO. These are mechanical foot orthosis devices for assisting foot motion. First written article on electronics media by Yates for thermoformed plastics reported in 1960. In recent times, Design development in AFO starts from passive to semi-active and then active AFO. Wolf, Ramsey

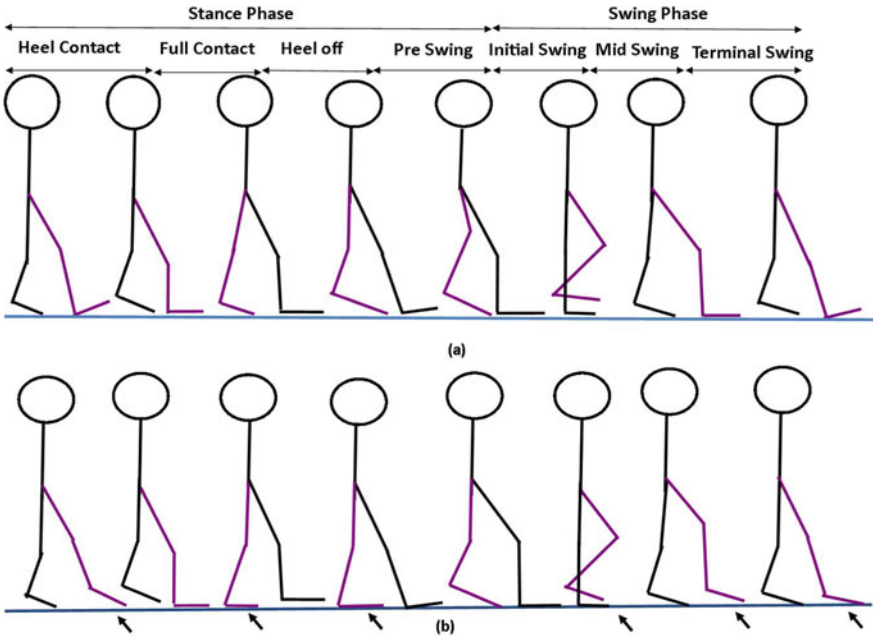

Fig. 2 Comparison between, **a** Normal foot gait and **b** Drop foot gait. Note: arrow indicates dissimilarity between normal and drop foot

worked, on Passive, non-articulated AFO having no Range of motion (ROM) between ankle and foot [13, 14]. It locks ankle position 90° to the foot (zero ROM) in standing or with some dorsiflexion (DL). Passive AFO lacks in rigidity, robustness, poor dynamic balance, and inability to adjust with walking conditions [15–17]. However passive AFO do not provides torque at stance phase for walking, is biggest drawback [7, 16]. Some researchers goes beyond designing and articulated passive AFO by adding spring to provide positive torque for walking propulsion [17]. Semi active AFOs have elastic mechanism works on magneto-rheological damping technology which manages the motion of ankle by angle sensors and current applied [17–19]. Kobayashi clinically determined rocker position of ankle and PL and DL moment by adjustable screws while Romkes and Brunner, compared dynamics with hinged AFO and found no significant difference in walking pattern but significant changes in knee parameters and peak power absorption of both AFO [10, 20]. Semi-active AFO does not provide any external torque to the system that leads to extra expense in total metabolic cost. To overcome these limitations of passive and semi active AFO, active AFOs were developed with robotics system, articulated and adjustable to PL and DL resistance. Gordon discussed about using pneumatic muscle to generate muscle power in ankle. This advancement generates required muscle force, peak torque, positive hip flexion, improved knee kinematics at constant and less energy losses between the pneumatic muscles [21]. However, active AFOs were very expensive in cost and have poor cost benefit ratio along with this these AFOs were heavyweight

Table 1 Position of markers

Body part	Number of markers	Positions
Shoulder	3	Right and Left acromion, c7
Pelvis	3	Right and Left ASIS, between PSIS and back
Thigh	3	Femoral condyle, great trochanter, lateral bar
Shank	3 on each shank	Fibula head, lateral bar, lateral malleolus
Foot	1 on each foot	Fifth metatarsal joint
Heel	1	Only for standing

due to sensors and actuator additional weight. This work discussed about patient eccentric, lightweight customized AFO according to its gait requirement based on kinematic and kinetics parameters obtained from gait lab. In present research work, human factors like weight of the AFO, easy don and doff of AFO and customization according to patient gait system is contemplated.

2 Data Acquisition

All gait kinetic and kinematic analysis was done at Gait Lab of Physical and Rehabilitation Medicine Department in PGIMER gait lab embedded with BTS motion capture system, 16 force plate, biometric EMG analysis and Sway analysis. Spherical marker system was used for 3D motion analyses and their respective positions were shown in Table 1. One patient with DF was selected for all these studies. All anthropometric parameters Weight (in kilogram), Height (in centimeter), Ankle diameter (in millimeter), Leg length (in millimeter) were acquired and stored in BTS SMART-clinic database software.

3 Fabrication Process

Polypropylene as a host material was used for fabricating process through Selective laser sintering In this method, Laser as a power source is utilized for liquify bed of material. A pictorial view of AFO is shown in Fig. 3.

4 Result and Discussion

Data obtained from GAIT analyses were processed and analyzed. Comparison of DF with healthy foot was done for better patient eccentric requirement (Table 2).

Fig. 3 3D printed AFO

Table 2 Comparison between normal foot and drop foot with and without AFO

Parameter	Gait cycle region	Maximum deviation	Maximum deviation
		Without AFO	With AFO
Ankle angle (in Degree)	Full contact	13.12	1.72
	Pre swing	7.52	0.19
	Initial swing	12.73	−3.21
	Mid swing	8.02	0.87
Ankle moment (N-m/Kg)	Full contact	0.71	0.24
	Heel off	0.42	0.01
Ankle power (W/Kg)	Full contact	−0.12	−0.02
	Initial swing	1.62	1.18

Out of various kinetics and kinematics parameters, the most dominating factors in gait analysis were shown in Fig. 4 which show ankle plantarflexion and dorsiflexion curve, Ankle moment and Ankle power in one gait cycle.

Major difference in DF and normal foot occurs at full contact region in case of all three curves due to inability of loading response in DF at heel strike and full contact phase. In initial swing phase, in normal foot, the power generated through spring energy is stored in foot during end of pre swing phase but in DF muscle inactivity or weakness tends to generate plantarflexion and low power. The decrement in ankle power and plantarflexion is compensated by the AFO but this is not at the extent with the normal gait. Patient under trial extends hip excessively in dorsiflexion range this results more ankle moment compared to normal range in during loading response and mid stance range. This movement in frontal plane leads to difference in values of ankle moment as compared to normal gait.

Here, optimization plays a critical role for decrement in the difference between normal values and DF value with AFO. However, absolute zero difference is impossible but minimum difference is the primary task of a customized AFO to make

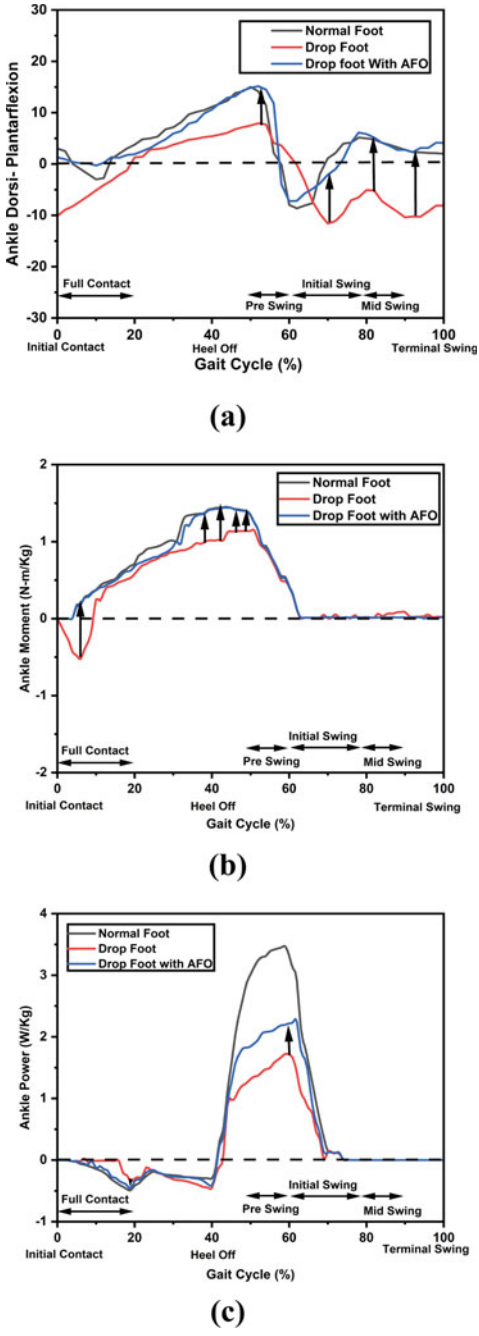

Fig. 4 **a** Ankle Dorsi-plantarflexion, **b** ankle moment, **c** ankle power variation with gait cycle

AFO better in performance and gait energy compensation close to normal foot. Optimization is based on height of AFO, thickness and material as input parameters and strength and stiffness are output parameters. The result of optimization based on Finite Element Analysis (FEM) is potential as a design tool before prescription of AFO. The cost of customization depends according to patients weights and data available from GAIT which does little difference economically in overall production of AFO, but these factors are relevant in GAIT. The cost associated with the fabrication process and host material of the AFO will be a dominating factor. Further starting material for fabrication is discussed in later section which could bring overall cost down because these fibers are readily available in nature and cheaper than conventional materials like metals and plastics.

5 Low Cost Host Materials

Use of Polypropylene (PP), Polyamides, Acrylonitrile butadiene styrene (ABS) and Carbon fiber composites as starting material had been widely used by researchers, but these materials either lacks in strength or effectiveness. Materials like plastics are inflammable and have better corrosive and rusting resistance. For AFO, there is no better material other than carbon fiber composite due to its desirable properties like high strength at low weight and corrosive inhibiting characteristics. Also at the same time great variability in terms of material makes possible to change its strength according to requirement, however these composites are very costly than other contemporary materials which makes it less attractive for use. In material domain, use of Natural Fiber Composite as host material is very less discussed for AFO fabrication [3]. Natural fibers composite like Kenaf, Kevlar with epoxy resins can have excellent mechanical strength that can bear load of an adult DF patient. These composites have better tensile strength compared to plastics, wood and some metals too, these composites also perform better in specific strength and specific stiffness [14]. Utilization of Natural fiber composites likewise is ideal for environmental morals, which isn't in the case of plastics and carbon fiber composites. For high performance tasks like running, stair climb, use of PP or ABS modular AFO connected from shank and cuff through customized carbon fiber strut could be a better and economical design [3, 14]. These hybrid AFO provides energy requirement in gait and PP or ABS, which provides better mechanical stability could also be possible and more economically acceptable choice rather than using whole AFO made of carbon fiber composites, but replacement of PP and ABS as natural fiber composite can be a greater impact in gait stability and low cost design [3].

6 Conclusion

The article is on customization of AFO for DF Patients and how a normal gait differs from DF gait. After data acquisition from GAIT lab and AM of AFO kinetic and kinematic studies has been done and performance of AFO is analyzed**.** Obtained curves depicts the customized AFO performs well in ankle angle and moment curves but lags in ankle power generation. Undersupply of energy and its impetus for appropriate synchronization with stride cycle could be discussed furthermore. The energy required during toe off period can be supplied through carbon fiber strut or hybrid AFO as discussed earlier. There is lack of optimality in stiffness and strength of AFO in other available studies this optimality studies are highly required and can be employed through optimal design input parameters. Natural fiber composites can be economical replacement material and hybrid AFO could show better result. Furthermore, 4D printing can be employed for more smart printing and which provides more independence to alter final material shape it future of manufacturing in AFO.

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Ergo-Studio—A Case-Study on Teaching and Learning Ergonomics in a Studio Mode

Gourab Kar

Abstract This case-study describes how a lecture-based Workspace Ergonomics course was transformed into a learner-centered Ergo-Studio that engaged with theory through the praxis of prototyping. The goal was to create a learning 'space' that invited students to actively participate in meaning making while providing a flexible structure for guided discovery. The paper introduces the context, describes strategies adopted for the transformation, and concludes with learnings from the experience. The following strategies were adopted to catalyze the active learning experience. First, real-world contexts that engaged with concepts relevant to the course were identified. Second, course timelines and student deliverables were prepared in advance. Third, a flipped-classroom model for content delivery was used. Fourth, there was a bias towards learning by prototyping. Fifth, students actively shaped their learning experience through research, design, prototyping and testing. Sixth, students self-organized into teams, delegated roles and responsibilities, and engaged in peer-learning. Seventh, digital storytelling as a medium of communication was adopted. And finally, the instructor's role was that of a facilitator and coach rather than a *'sage-on-the-stage'*. Creating a successful learner-centered experience requires a fine balance of structure while providing the freedom to navigate ambiguities in the learning process. Students were enthusiastic of the Ergo-Studio since it built on their design training, challenged them to apply knowledge in a real-world context, and offered a sense of ownership. If used effectively, experiential learning can empower students and instructors to engage with the course intellectually, creatively, physically, socially, and emotionally to enhance the teaching and learning experience.

Keywords Experiential learning · Workspace ergonomics · Learner-centered course · Project-based learning · Peer-learning · Flipped classroom

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1 Introduction

The traditional model of teaching and learning places the instructor as the central figure—one who has the knowledge and transmits it to students, who in turn memorize this information and later reproduce it on an exam [1]. This process of teaching and learning—called the transmittal model—assumes that learning is a one-way process with students being passive receptors of knowledge transmitted from the instructor [2]. Recent theories of learning—based on the constructivist model—suggest that knowledge does not come packaged in books, journals, computers, and other sources, and cannot be transmitted intact from the instructor to the students. Instead, knowledge is a state of understanding that exists in the mind of the individual—the individual constructs this knowledge through a process of making sense of the information based on what she already knows [3, 4].

In recent years, academics have begun to adopt a dynamic view of learning by placing experience at the core of the learning process [5]. Building on the work of educationists who have advocated a central role for experience in their theories of human learning and development, experience-based learning focuses on a learner–centric approach that is driven by the discourses between action/reflection and experience/abstraction. In the practice of teaching and learning, there has been a qualitative shift from a lecture-based method to an open-ended, process-oriented approach that values inquiry, reflection, case-studies, and problem-based learning, as well as collaborative and self-directed learning [6]. This active, participatory, and experiential process of teaching and learning seeks to prepare the next generation of students who need to acquire effective communication skills, a penchant for creative and critical thinking, and a mindset for problem-solving in a world that is increasingly complex and unpredictable [7].

This paper describes a case-study of how a lecture-based Workspace Ergonomics course was transformed into a learner-centered Ergo-Studio that engaged with theory through the praxis of prototyping. The author had taught the Workspace Ergonomics course for a couple of years to 3rd-year Bachelor of Design (B. Des) students at the National Institute of Design (NID) Ahmedabad. The goal for the course was to create a teaching and learning ‘space’ that invited students to actively participate in constructing meaning, while providing a flexible structure for guided discovery. The paper introduces the context for the course, describes strategies adopted to shift from a lecture-based to a process-oriented approach, and concludes with learnings from the experience.

2 Context

The courses at NID Ahmedabad are module based—that is, courses in each semester are offered in sequence rather than in parallel. While from a pedagogical perspective there are benefits and drawbacks of sequential vs. parallel modes of scheduling

courses, this paper focuses on how the course was restructured while retaining the modular nature of the course. The 2-week module on Workspace Ergonomics was the third and final ergonomics module in the B. Des curriculum. Modules in prior semesters had introduced the B. Des students to theory and concepts of physical and cognitive ergonomics.

The 2-week module on Workspace Ergonomics focused on matching peoples' abilities and capacities at work to the physical work environment with a goal to improve performance, health and well-being. In previous years, the course had been taught in the traditional lecture-based format and student learning was evaluated through paper-based exams and take-home assignments. Ergonomics being an applied science, and with B. Des students being trained to be professional designers—the course was re-formulated to bring in a process-oriented approach with project-based learning and peer-evaluations. In this paper, the author highlights eight strategies adopted to transform the passive, instructor-centered teaching method into an active, student-driven, project-based learning experience. The paper adopts the narrative style of a personal reflection rather than the standard template of a scientific paper as the former is better suited to highlight the change in the teaching and learning pedagogy highlighted here.

3 Strategies

3.1 Engage with Real-World Contexts

In the two years of teaching this course, the author formulated research-driven, design-build projects that engaged with real-world contexts at the intersection of people, environments and work. In year one, students studied the unreserved ticket counters in Ahmedabad railway station to analyze challenges in human–environment interactions. Findings from the research were synthesized to design, prototype, and test solutions that applied concepts of workspace ergonomics to improve human performance, health and well-being in the ticketing workspace. In year two, the context was limited to the NID campus at Paldi in Ahmedabad, to obviate the logistical challenges of research and design in an out-of-campus location. Student teams studied workspace needs of three work environments on the campus—(a) in the studios and classrooms, (b) in a newly formulated electronics laboratory, and (c) in the security booths at the entrance to the campus. Students in teams of five used a combination of observational research (see Fig. 1), user interviews and user surveys in these work environments to discover unmet user needs and formulate an actionable design brief. Next, they applied concepts of workspace ergonomics to design, build, and test full-scale workspace prototypes with the intended users. In both years of this course, the use of the city and the campus as a working laboratory to engage with real-world contexts transformed learning into an experiential activity. Perhaps, more

Fig. 1 User research for the multi-purpose table-cum-lectern project

importantly, these contexts challenged students to apply the theory and concepts of workspace ergonomics in a real-world *live* project.

3.2 Prepare Groundwork in Advance

Identifying potential real-world contexts had to be followed up with establishing contacts with *clients* for whom these research-driven-design projects would be executed. In case of the railway reservation counter study, prior approval was sought and received from the Divisional Railway Manager's Office in Ahmedabad; schedules for the site visits were worked out in consultation with railway staff working in the ticket counters. The analysis phase of the study was conducted on-site; while the synthesis phase involving design, prototyping and user testing was conducted on-campus.

Due to logistical challenges encountered in involving external *clients* in the first year of the course, the next year's research focus was limited to real-world contexts within the campus. This simplified logistics of research and enabled real-world users to test solutions designed by students. In both the years, the groundwork for the course had to be prepared well in advance—requests for visits, approval of research protocols, procurement of prototyping materials, and scheduling of timelines and deliverables had to be finalized months in advance. Given that this was a 2-week (12 working days) course it was vital to plan a detailed hour-by-hour schedule while allowing for a degree of operational flexibility to account for last-minute changes.

3.3 Restructure Course Inputs and Schedule

In previous years, the workspace ergonomics course used a teacher-centric approach with in-class lectures introducing students to the theory and concepts of workspace ergonomics. The students' learning was evaluated through individual projects

assessed by a presentation as well as a written exam using a multiple-choice type of question paper. In contrast, this course was restructured so that the teaching and learning process was student centric. Embracing the idea of the flipped classroom [8]—the students were provided online inputs on human-centered design [9] and introduced to the concepts of workspace ergonomics [10] prior to in-person classes. The class time, or rather the studio time, was devoted to on hands-on activities that prepared students to engage with the real-world context. In class lectures were kept to a minimum; peer learning and discussions were encouraged. The course schedule was re-designed so that instructor feedback sessions were synchronized with the research, design, prototype and test phases of the design-build project.

3.4 Students as Active Stakeholders in Shaping Their Learning

Students were provided real-world contexts in which they had to—(a) analyze a workspace to identify ergonomic challenges, (b) develop a design brief to address the challenges, (c) design, prototype, and test a workspace solution, (d) evaluate the workspace solution based on ergonomic criteria, and (e) communicate their research-informed-design findings to the community. The instructor's role was to define the context and facilitate the process of learning. Students actively shaped their learning experience—they took the initiative to define research questions, choose the methods of analysis, make decisions on design directions, and they were responsible for the design, fabrication and testing of the workspace prototypes.

For example, student teams analyzed the range of activities in the design studios at NID Ahmedabad to uncover the need for a multipurpose table-cum-lectern that could respond to the needs of different user groups and support a range of studio activities (see Fig. 2). Similarly, by investigating the work schedules and operational needs of security staff stationed at the entrance gates to the campus, students were able identify the unmet needs in the human–environment interactions. They responded by designing a dynamic seating solution which enabled security staff to be in a resting posture while remaining alert at work. In both instances, students took the lead in analyzing the problems in human–environment interactions to design, build and test optimal workspace solutions in response.

3.5 Learning Through Prototyping and Testing

Ergonomics is an applied science that aims to optimize human performance, health and well-being in human–environment-technology interactions [11]. Since the B. Des students were being trained to become product designers, the course pedagogy was re-designed with a bias towards prototyping and testing. This shift enabled students

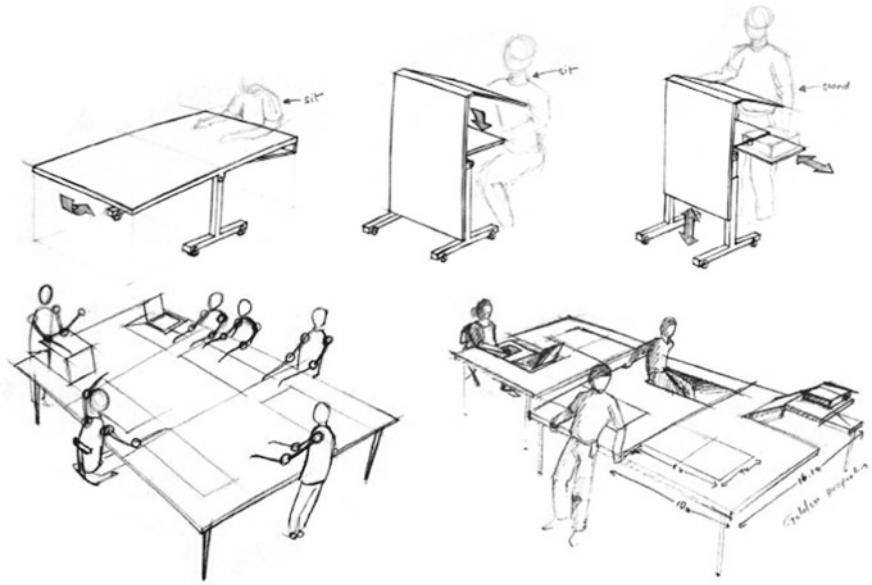

Fig. 2 Concept sketches for the multi-purpose table-cum-lectern project

to demonstrate their understanding and application of workspace ergonomics in a real-world context. In year one, students built a full-scale experience prototype of a railway ticket counter and simulated across the counter transactions to demonstrate inclusive access and improved performance. In year two, students designed and tested three full-scale prototypes—a lectern-cum-table arrangement for the classroom (see Fig. 3), an electronics workbench for a new laboratory, and a dynamic seating solution for security personnel at the entrance to the campus. These workspace design solutions were tested with real-world users to evaluate user performance and demonstrate application of workspace ergonomics to real-world contexts (see Fig. 4).

3.6 Teamwork and Peer Learning

The focus of the course was to create a learning ecosystem where teamwork and peer learning were crucial pedagogical elements to aid the understanding and application of workspace ergonomics in real-world contexts. Students self-organized into teams, delegated roles and responsibilities, and engaged in peer-based learning. The emphasis on teamwork reflected the need for students to navigate challenges of interpersonal dynamics, and tested their abilities to lead, manage and contribute as team members. Peer-based learning enabled students to have more time for individualized learning and direct interaction between peers promoted active learning [12]. In

Fig. 3 Prototyping the multi-purpose table-cum-lectern

Fig. 4 Testing the multi-purpose table-cum-lectern in various modes of operation

addition, the adoption of peer-based learning fostered social skills needed to coordinate and cooperate as team members and de-emphasized the role of hierarchy in the instructor-student relationship [13].

3.7 Digital Storytelling as a Medium of Communication

The course embraced use of digital storytelling as a means for research, analysis, and communication. Given the ubiquity of video-capable mobile phones and the popularity of online video platforms amongst the peer-group, the final project deliverable was a digital storytelling assignment that succinctly communicated their research process and product outcome. Students used video as a tool to not only study user behavior through time and motion analysis but also to demonstrate the ergonomic benefits of the workspaces which they had redesigned. Teams had to tell their story through a short 5-min video. The digital storytelling process entailed creating a script, organizing the video sequences and stills, and crafting a compelling story using video editing software. While the novelty of this approach enticed students to think beyond confines of a traditional assignment, there is need for further research on how the use of digital storytelling tools can reshape the teaching and learning process [14].

3.8 Instructor as Facilitator

And finally, the instructor took on the role of being a facilitator and consultant. During the initial analysis phase of the project, the instructor facilitated the students' interaction with the course material and with each other in the act of knowledge creation. Later, during the synthesis phase of the project, the instructor's role shifted to that of a design consultant who would guide students in the design-build-test phase. This facilitator-consultant approach necessitated a considerable shift in the instructor's role—moving away from the venerable position of the *'sage on the stage'* to becoming a *'guide on the side'* who provides context, orchestrates resources, and poses probing questions to simulate students to find their own answers [15, 16]. It must be emphasized that the role and duties of the instructor extended way beyond the two-week duration of the course. The instructor had to plan and organize the sequence of activities at least a couple of months prior to start of the course.

4 Conclusion

The adoption of the Ergo-Studio method of teaching transformed the learning experience of the workspace ergonomics course from an instructor-centered approach

to a student-centric process. The use of real-world contexts and a design-build-test method of problem solving inspired the students, offered them an opportunity to shape their learning experience, and built on their skills and prior knowledge. Beyond the strategies enumerated previously, there were a few other factors which made this teaching and learning experience successful. The instructor's prior experience as a professional designer and as an academic researcher helped bridge the *gap* between the world of academia and the world of practice. The small batch of 15 students enabled individualized attention and facilitated one-to-one interactions with the instructor. As the students were in their 3rd-year of the B. Des course, they were well versed in design and prototyping, and had access to high-quality in-house fabrication facilities. Perhaps, the use of the city and the campus as a living laboratory provided additional motivation for the students to work on the *live* projects impacting the community.

While the course could be considered a successful experiment in introducing an experiential learning approach, there are some limitations that need to be enumerated. First, there was no formal measurement and comparison of learning outcomes between the previous instructor-centered method and the new learner-centered approach. A formal comparison of these two contrasting learning styles will be valuable information for future instructors. Second, students were graded on the evaluation of group outcomes; there was no fool-proof and effective way to evaluate individual student performance. Third, the design-build-test approach was feasible due to the prior design training of the students as well as the instructor. In absence of a certain level of design and fabrication proficiency in the student groups such a design-build course will be difficult to operationalize. Fourth, the small class strength of 15 students ensured individual attention and simultaneously working with three groups of 5 students each, was manageable. Scaling up the same teaching and learning approach to a larger group of students and student teams may result in logistical challenges. Fifth, the modular nature of course enabled students to devote the entire duration of two weeks for the project. The same may not be the case when such a method is adopted for academic schedules that have multiple courses running in parallel.

In conclusion, creating a successful learner-centered experience requires a fine balance of structure to manage complexities of open-ended, real-world contexts while providing freedom for students to navigate the opportunities and ambiguities inherent in the learning process. The B. Des students at NID Ahmedabad were enthusiastic of the design-build-test method since it scaffolded on their prior training in research and design, challenged them to apply knowledge and skills in a real-world context, and offered a sense of ownership for the project. If used effectively, experiential learning can empower students and instructors to engage with the course intellectually, creatively, physically, socially, and emotionally to enhance the teaching and learning experience.

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An Empirical Study on Cognitive Impartment of Knowledge in Children Through Augmented Reality

Sndipan Bhattacharjee and Bhaskar Saha

Abstract Utilization and implementation of modern technology have become a necessity in various domains of society for proper and updated growth in that particular sector. Children are most influenced by this wake of modern technology in their daily life. This paper aims towards investigating the amount of interest generated among children through their present academic course curriculum and proposal of a design training module for children. The module would essentially deal with the comprehensive representation of educational information through AR. The advantageous aspects and challenges of using AR in the education sector, were tallied by conducting a survey among children and their parents using module prototype and questionnaire. An in-depth analysis of the subject matter was done about proper utilization and implementation of the proposed aspect. Augmented Reality (AR) being an advanced technology for a big chunk of the masses, especially children, could prove to be an interesting element to Indian education scenario. The study ventures through the possible future scope of the module into generating cognitive impartment of knowledge while also introducing fun and engagement into study materials through Augmented Reality.

Keywords Augmented Reality · Education · Design module · Interaction

1 Introduction

Technological innovations constantly attribute to the components of society and in turn contain, manage and deliver innovation [1]. Interaction between people and technology establishes a rationalized communication mode, that helps to understand and overcome complex matters pertaining to society [2]. It has influenced young peoples' lives to an extent that it has become inseparable from day to day livelihood [3]. In a study done by Sally J. Mcmillan and Margaret Morrison, it was evidently depicted that people have developed a certain dependency on technological aids for

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managing their daily activities to maintaining social communities [4]. Well-organized innovation reflect that the effect of new media innovation or technologies are very conspicuous and significant in most domains of society, which is often with better intentions [5, 6].

1.1 Influence of Technology on Children

Children are the most influenced age group of advanced media, which is a separate section of new media technologies. There exists a significant discussion and literature on the overall impact of digital media resources on children. The engagement that is created by digital media among children is enrapturing and they develop propensities towards it [7, 8]. The measure of time spent by the youth segment of the general public or computerized stages in generous and it expands the interest level of utilizing it habitually [9]. It has been noticed regularly that the new generation is very sharp at utilizing the new technologies such as phones, tablets and computers and also possess a certain level of expertise while using [10, 11]. The primary reason for the influence of digital media on children is that they are encircled by its resources and are straight forwardly or roundabout way constrained to utilize it. As the substance of viewing, has an emotional alleviation in children, their parents and guardians consider the scope for implementing digital media-based technologies for progressive and creative thinking or imaginative reasoning [12, 13]. According to several experiments conducted on the use of digital technology into the creation of source materials that are developmentally appropriate for imparting knowledge and evoke the roots of critical thinking in children [14, 15]. The last decade evidently revolutionized the perception of children's learning through the development of digital media, though exist literature and counter arguments about other aspects of the matter. Appropriately suitable digital media content could be created and used for imparting quality services for the users [16, 17]. Utilization of such advanced media content in the educational program could achieve a radical improvement in youngsters and children in exhibiting physical, social, passionate and intellectual advancements [18]. Children are often encouraged by their parents and adults to indulge in digital media content to keep up a happy and contented mood in recent times and this has led to habit of investing time on digital platforms by the younger section and ease of work for their parents [19, 20]. According to a study conducted by De Jong and Bus, it is reflected that use of digital content along with parents assisted learning could make notable difference in imparting knowledge [21].

1.2 Augmented Reality and Its Influence on Children

Augmented Reality (AR) has found its share of popularity among the masses in recent years and continues to grow further. In general, AR is considered as a concept

which is implemented on various domains of innovation instead should be viewed as a technology that could bring more instructiveness and engagement to those domains. As a result, educators, researchers and designers could possibly find more productivity and efficiency in their work [22]. Augmented Reality, has made the process of learning futuristic and impactful than ever before. It allows the users to interact with the virtual elements of a particular subject matter, creating an immersive experience in the real world [23]. Group tasks that require a well-coordinated team work could have the training process made easy through AR. Groups could also share and simultaneously view data in virtual environments, that would bring more comprehensiveness in a particular work [24]. Critical thinking could be induced through playing intuitive games that serves the purpose of both entertainment and knowledge. These games have higher effectiveness when tagged with virtual environments [25]. Story and fantasy books for children could be made more interesting and appealing with the implementation of Augmented Reality. Children could be a part of their favorite fantasy story and could also interact with the elements of the story [26].

1.3 Education for Children with Augmented Reality

Particularly in classrooms, the productivity of the students is enhanced, if there is a common workspace for them. When AR is introduced in classroom learning, the subject matters are elaborated thoroughly with a common perspective of all the students. The entire virtual interaction gives out a sense of natural face to face interaction in the real world for the students [27]. Learning through AR supported resources could be fun as well as productive for the children at home. There is significant positive behavioral change in children and cognitive attainment, when parents assist the children in using AR technology in studies [28].

In this paper, it was intended to explore the implementational areas of Augmented Reality in educational resources for children, to come up with a more effective and comprehensive process of imparting knowledge from a tender age. It has been taken into consideration that children might need assistance from their parents in various aspects such as studies and handling technological gadgets and so, perception of the adults plays a vital role. The overall user needs and perception was addressed through a twofold survey conducted in Kokrajhar, Assam, India. It was to put the functionality of the technology into actual application for imparting knowledge into children.

The aim of this paper was to propose a hypothetical AR content, dedicated to children's education that facilitates seamless learning process. The objectives that were desired to be achieved through this paper were to establish a proposal of AR implementation into education for children both at school and home. The proposal would also ensure quality learning resources that helps in retention of details for children.

2 Design Process and Method

See Fig. 1.

2.1 Methodology

In correspondence to initial discussions, it was comprehended that there exist multiple scenarios for children and their parents, in which parents encourage children to indulge into the digital media and its elements from a very young age. In present times, the encouragement from parents regarding the use of technological devices by the children, usually come from the fact that tasks become easy to complete, such as feeding them and keeping them engaged and hooked into something interesting. Due to these, the screen time of the children has increased drastically to 35% in modern times and yet the actual outcome in gaining knowledge and gathering useful information, remains somewhat debatable. Parents deliberately look for an alternative digital media content that engages children in such a way that they are thoroughly entertained while imparting valuable learning and knowledge. Figure 2 depicts a scenario where parents encourage children to indulge in technology. Children too, might find it interesting and would essentially increase the curiosity level in them. In this context, an innovate approach is required, so that the current trend, where children have a huge exposure of digital content could be somehow utilized to impart quality knowledge. The typically existing educational content that contain graphical representations, found on digital medium and physical form are mostly in two-dimensional form and this was a crucial aspect in opting for a detailed user study.

The emotional aspect was also taken into consideration as it was required that the children must get a platform where their element of interest and curiosity is infused with educational information. As discussed earlier, children are keen into using technological gadgets and specially smartphones and tablets so, the content must be delivered through these devices to have a maximum reach among users. All

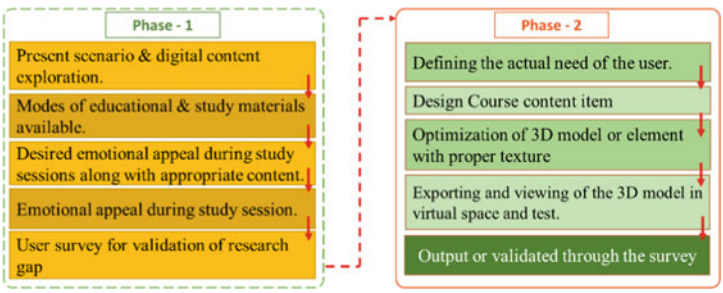

Fig. 1 Follow diagram of design process and methods

Fig. 2 **a** Parents encouraging to indulge in technology and devices, **b** interaction with children and their parents

these essential criteria were taken into for choosing Augmented Reality as the design approach.

Before the actual implementation of AR into the subject matter, it was very crucial to comprehend the user's actual needs and the obstacles faced with the present scenario while imparting educational information. As parents and guardians are mostly involved in guiding the children in both their education and technology, it was very essential to enquire about their perspective towards the approach. As quality user engagement is also a crucial factor for having a wide coverage of users and could be addressed through an immersive experience so, the inclusion of possible digital elements was also considered.

The entire study was partitioned into two phases, first being a in-depth survey regarding the perception and needs of the users and the second a prototype and discussion survey with design based students along with academic professors and teachers. Industry professionals and parents were also reviewed with the prototype and feedbacks were recorded accordingly. Figure 1 shows the entire design process of the approach.

2.1.1 Phase-1

The first phase of the study deals with the emotional state of children while doing their regular academic studies and tasks. The emotional stage refers to the feeling of lethargy and activeness a child goes through while doing a particular task. In this section the exposure of digital content on children was also taken into consideration as duration of screen time use and view were noted accordingly. This was mainly done to find out a solution for the increasing screen time of children into a useful and interesting study task. This phase also ventures through the existing study modules that are available for the children and are being used on regular basis. These existing modules include textbooks, e-learning sites and other education and learning based packages. All these modules were reviewed in respect to the level of curiosity a

child has while going through them, interactivity and versatility of the content for the children. The emotional state of the children was given utmost importance as it is this factor that determines the gain from a particular educational content. A low emotional state could lead to just viewing of the content without the actual gain in knowledge and understanding, while, a stable emotional state in children could help in proper comprehension of the subject matter along with its contents displayed. While venturing through the aspect of emotional state in children during study sessions, it was also very crucial to know exactly what emotions that desired to be felt while studding, as this would immensely help in coming up with an interactive solution so that the interest level of the children is intact and hence would increase their curiosity in doing it. Having explored the discussed aspects of cognitive learning, a proposal for an alternative mode of learning was made to children in the locality, who could give responses on the various ways the proposal could be enhanced for a suitable user base. Once the responses were recorded from all the necessary aspects of the design process, a questionnaire-based survey was approached. The survey was conducted among thirty individuals in Kokrajhar, Assam, India, using a questionnaire containing six questions. Among the thirty respondents twenty happen to be parents of children studying in classes ranging from one to five and are in the age group of five to eleven years. The other ten respondents happen to be the people who have witnessed such scenarios.

As mentioned, the questionnaire had six questions regarding cognitive learning process and to enquire about the actual need of the children so that their study sessions could be made more interesting and they could also gain in a better way.

Question 1, talks about the current influence of technology and digital media content on lifestyle of people and habits that has formed due to it. It explores the crucial aspects of life that seem unimaginable without the aid of technology and digital media. The respondents were asked to state their perception on it. Question 2 states the most influenced group to be the children and their expertise in using gadgets along with digital medium exposure. Scenarios are set as an example to show how they are involved in various digital content viewing. The respondents were asked, if they thought technology and advancements have a firm influence on children. The Question 3 talks about the involvement of parents and guardians in encouraging their children to indulge in technology and digital media content. A scenario is set as an example, where it is described how and why parents encourage their children to do so. The elders deliberately want their task involving children, to be completed with ease and without disturbance. The respondents were asked if they thought this practice was healthy for the children. Question 4 explores the area of cognitive learning and imparting knowledge in details. It talks about the necessity of quality knowledge that involves both entertainment and learning that collectively helps in overall development of children. The respondents were asked if they thought, children must be offered with an interactive and immersive procedure of studding. Question 5, deals with the existing modules of education such as books, smart classes, e-learning sites and their representation of content. It primarily talks about the pictorial representations of content in two-dimensional form that allows the reader to view it from a single point of perception and might create difficulties for some to understand

properly. The respondents were asked if they thought the current modes are suitable enough for the children. Question 6, introduces a hypothetical procedure of imparting knowledge into children. The implementation of Augmented Reality technology through smartphones and tablets to view the pictorial representations. The added-up feature of viewing the pictorial representations in three-dimensional space and in real time. The respondents were asked if they thought this type of study module would be efficient for increasing the performance of the children.

2.1.2 Phase-2

The second phase of the study deals with the actual practical implementation of Augmented Reality into educative information for children. The approach was made to properly address the children for their actual needs during a study session so as to keep them engaged in the activity and made them come back again and hence increasing their interest level. The manner of display and viewing was also taken into consideration and to keep it generic smartphones and tablets were chosen for the viewing of the three-dimensional space. The entire idea was to pick some simple elements from different academic subjects that required a graphical or pictorial representation and then convert and deliver it in a virtual three-dimensional space that allows interaction. The subjects were mainly science, geography and object identification, so that the entire chosen age group of children could be properly addressed. For building the prototype it was essential to have AR elements and content that could be displayed through smartphone and tablets. The devices to be used must also support AR camera, was also a necessity. To overcome this obstacle in a more generic manner Spark AR Studio was taken into consideration for creating AR content. The solution for AR supported camera was also found as the studio connects to social media platforms, which fulfil this requirement. The entire flow of Phase-2 has been described in Fig. 3.

The first step into creating the prototype was to come up with 3D models of the selected elements in .obj format as it is one of the diverse formats in among AR studio platforms. Models with heavy information are difficult to manage in AR environment when viewed through a device's camera. So, the models had to be optimized to the possible extent, so that it retains required look and feel and simultaneously is

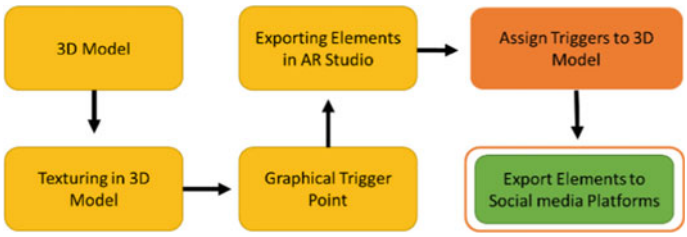

Fig. 3 Follow diagram of technical requirements

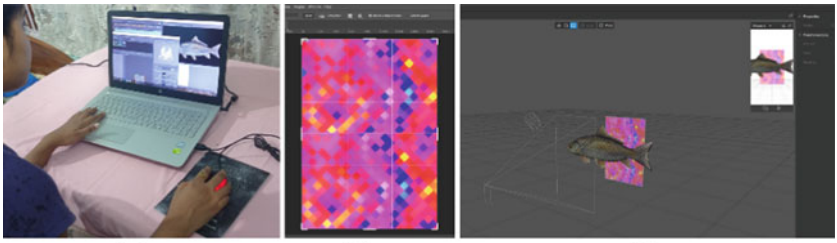

Fig. 4 **a** Creation and optimization of 3D models, **b** generating trigger points help of design software, **c** exporting the models with the triggers

supported in the AR camera. After proper optimization of the models, they are needed to be textured accordingly for realistic representation. Figure 4 shows the process.

For viewing any AR content and element in a virtual space requires the content to be triggered by a trigger point and so the second step is involved into creating unique trigger points for the AR content. The trigger points are more efficient and accurate when they are made up of atleast two or more differing colours. Random repetitive patterns were created containing three different colours, as a unique trigger point. Each AR element chosen from various subjects has a unique and dedicated trigger point for generating in the virtual space. The third and most crucial step for creating the prototype is to turn the models and trigger points into AR elements and then to export them to cameras for viewing in real time. The optimized 3D models are exported in Spark AR Studios where the orientations can be altered in 3D space along with the applied textures. The triggers are assigned to the models in the AR studio and exported to the social media platforms linked to it. The social media platforms that are connected to the Spark AR Studio usually come with AR supported cameras and are accessible through normal smartphones and tablets. Once the AR elements are exported to AR supported cameras, the fourth step is to try out the implemented content in different lighting set ups for exactly know the best lighting conditions for triggering the AR content in the three-dimensional space. The fifth step involves the validation of the proposal from the children so that the actual feasibility of such a proposal could be properly understood. The children were presented with the AR content and were reviewed on the basis of interactivity and immersive-ness. The responses were recorded and incorporated accordingly in the prototype proposal.

Once all the essential parts of the second section of the study was completed, it was time for a discussion survey done along with doctors, professors, teachers, industry experts, parents and guardians while the prototype was showcased to them and its purpose was explained. As children may require the assistance of adults to operate through some of the features of the prototype, it was extremely essential to know their perception towards it. Students from design background were also consulted as they might provide with crucial inputs regarding the user experience and its available scope in the proposal. Figure 5 shows the discussion sessions conducted.

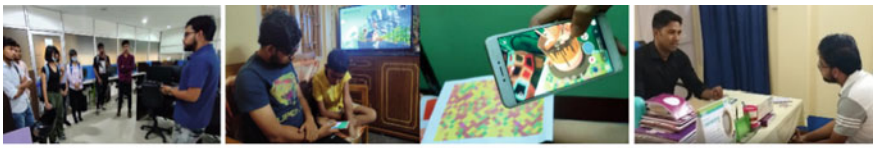

Fig. 5 **a** Interaction with students of design background, **b** interaction with children with prototype and **c** interaction with Doctors and Parents

3 Result and Discussion

3.1 Results of Phase-1

According to the results obtained through the survey conducted in Phase-1, Question 1 saw 50% of the respondents to agree with the fact, 30% of the respondents strongly agreed, 10% disagreed and 10% strongly disagreed. In Question 2, 40% of the respondents agreed with the fact, 36.7% strongly agreed, 6.7% disagreed and 16.7% strongly disagreed. Question 3 had 36.7% of the respondent to agree with the scenario presented, 30% strongly agreed, 16.7% disagreed and 16.7% strongly disagreed. In Question 4, 40% of the respondents agreed, 36.7% strongly agreed, 10% disagreed and 13.3% strongly disagreed. Question 5 saw 30% of the respondents to agree with the proposal, 40% of the respondents strongly agreed, 16.7% disagreed and 13.3% strongly disagreed. According to the proposal put forward in Question 6, 23.3% of the respondents agreed, 46.7% strongly disagreed, 13.3% disagreed and 16.7% strongly disagreed.

The graph of the results obtained is depicted in Fig. 6.

3.2 Results of Phase-2

The children who participated in the prototype survey took up the process of using the AR feature interestingly. The emotional drive and appeal that was quite essential for them to continue their study sessions was seen to be closer in reach with the implementation of AR technology.

According to the discussion survey, the feedbacks were noted down for upgradation of the concept. The feedbacks along with respondent data has been presented in Table 1.

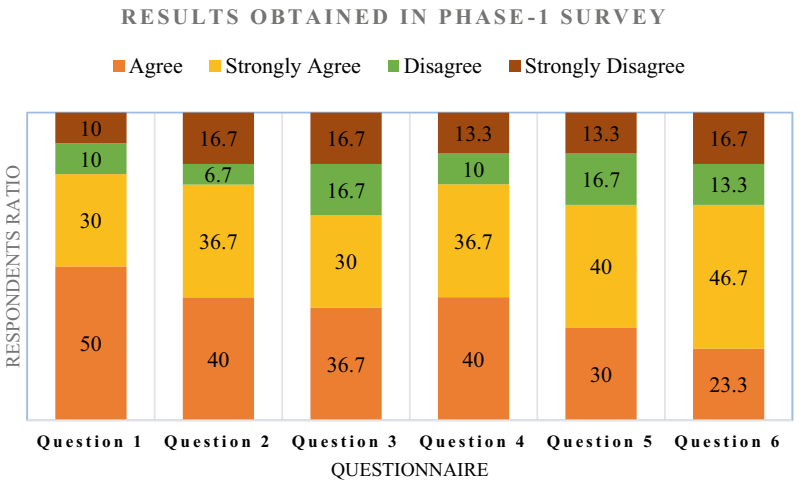

Fig. 6 Results obtained during Phase-1

From the feedbacks collected, it is evident that the idea in whole could be an innovative approach towards imparting knowledge. Children could have an immersive learning experience and that might help them understand better, the concepts taught. The present modules of learning could also incorporate the concept of Augmented Reality into their study materials. To have a coverage of all the subject areas of learning, the concept would need a vast storage capacity for all the elements and models that would be required. So, a proper planning out for all the possibilities into actual implementation of the concept must be chalked out and addressed properly. Incorporation of achievements and rewards could bring about a drastic boost up for the concept in for of games and activities. Moreover, the negative effects of increased screen time that leads to physical lethargy and lack in social skill development, is equitized by the fact that the concept would somewhat require a screen time for the children which is almost equivalent to the present scenario and yet due to the learning aspects of the approach, it might be beneficial to an extent. The entertainment factors remain as one of the crucial factors that would determine the regular engagement of the children with the study materials. The involvement trend of children with technology and devices could be used in a better way for cognitive learning and imparting quality knowledge to them. This aspect of imparting knowledge to children for better communication and comprehension is of utmost importance in the design approach.

Table 1 Feedback table of the discussion survey

Name	Feedback
Dr. Prakash K. Nayak, Asst. Prof. Dept FET, CIT Kokrajhar	Innovative approach. The present modes of e-learning could have a separate section, where similar ideas could be implemented
Mr. Avijit Paul, Asst. Prof. Dept Civil, CIT Kokrajhar	The practical implementation of the idea has a vast area to cover and, in that respect, a more stable foundation is required for future elaboration
Dr. Nabajyoti Majumdar, Asst. Prof. Dept IT, CIT Kokrajhar	A very positive approach. Though the user engagement could be possibly enhanced by adding achievement and games for the children
Dr. Zunikar Ali, Doctor, RNB Hospital Kokrajhar	The proposal would require a fair amount of screen time for the children but they are still having almost same amount now without it and so the idea might actually be of use as it is for the benefits of the children. Further, similar concept can be used to demonstrate complex anatomical structures for older students too
Mr. Sanjib Lodh, Teacher, Siishu Kalyan School, Kokrajhar	The proposal could be fruitful for the growing children. Learning is fun in this way and teachers could also put in their effort to build a entertaining learning environment
Mr. Pradipta Sen, Industry Personnel, GeoTech Informatics	There is scope of the project into actual implementation. Planning of the entire concept into working is needed to be done very crucially and minutely
Ms. Tuhina Bose, Teacher, Shishu Kalyan School Kokrajhar	Interesting idea. It could be beneficial for the children as the can interact with what they see on the screen. Learning could be made fun
Mr. Bhupen Biswas, Officers, SBI Kokrajhar	Children are mostly hinged to mobile phones these days and with concept like this can be used to make them study with mobile phones
Mr. Akash Ghosh, Businessman, Kokrajhar	The idea can be implemented alongside the existing modes of imparting knowledge and not as an alternative of them. This is because
Ms. Barsha Biswas, Housewife, Kokrajhar	If it is fun and entertaining, children will definitely like it. The incorporation of fact and elements to give them quality learning experience is very essential

4 Conclusion

While addressing the issues related to the implementation of Augmented Reality in the educational sector through an hypothetical design approach, a number of critical obstacles could possibly be solved such as difficulty in understanding concepts, low emotional state during study sessions and lack of proper communication for facts.

Through the above investigation on the need and want of an innovative mode of learning and education for children, could possibly prove to be very beneficial to them. By the implementation of ideas and perspectives of Augmented Reality in day to day study and learning applications, might rise the possibility of coming out with innovative service designs. The collaboration of students and people from various technical and aesthetical fields would be necessary. With the possible scope of future work elaborated in discussion, could prove to be a helpful tool to the masses. Extensive and intensive work on the elaboration of potential of such an approach establishes a future possibility that it could be used for complex anatomical, mechanical and chemical facts and data in an interactive and immersive manner.

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Virtual Reality Reducing Cognitive Load in Travel Planning

Aanchal Krishna, Tushar Amin, and Tanmayee Puntambekar

Abstract Planning and executing a vacation can be an exhausting process. Several factors influence vacation planning. The most important factors are the destination and the accommodation. People face difficulties in deciding the destination that allows them to experience the location with a suitable accommodation. Social media plays a crucial role in promoting different destinations and providing associated travel information influencing travelers to finalize a location. Deciding the location on the bases of online content often causes disappointment. Virtual reality has been proven earlier to enhance the experience and streamline the way information is presented to the viewer. This research aims at exploring the possibility of including further technological advancements to reduce the extraneous cognitive load taken by a tourist while planning a vacation. The objective of the research is to understand the multi-stage process in tour planning in order to aid stress free and quicker travel planning. The data was collected by survey and interviews to note the travel routine and understand the process of decision making and the reasons leading to informational overload while planning a trip. The data collected was analyzed both qualitatively and quantitatively. Enhancing the tourist's experience by incorporating technology in the tourism industry reduce the bombardment of irrelevant visuals and information and simplify the decision making process. Incorporating virtual reality in the planning stage of a vacation will increase the confidence of the tourist in their travel decisions and encourage them to explore a wider variety of options in lesser time before booking.

Keywords Virtual reality · Travel planning · Cognitive load reduction · Travel experience · Cognitive ergonomics

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1 Introduction

Tourism and vacations are considered as an integral part to enhance the quality of life [1]. Tourism industry is a highly information driven industry and hence has been constantly adapting the modes of information dissemination right from mouth to mouth publicity to internet based social media communication. The rapid increase in social media communications has affected the way vacation planning has been perceived and executed [2]. The information about the destination, stay, local food, photos, reviews and star ratings are the major factors which are considered for deciding and planning the vacations. Online content creators such as travel bloggers, influencers, and photographers create posts as per their perception about the location which influence the traveler's decision. It has been proved that blogs are not defined by the content but by the way the blogger uses it. Also it is easy for a traveler to connect to the blogger and gain firsthand information of their experience. Hence the perception of the information may differ person to person [3]. Most of the travelers decide the vacation destinations based on such online information which can cause disappointment to the travelers when they visit the place. Disappointment is the negative emotions evoked in the traveler's mind due to inadequate service, difference between photos and actual location, high expectations set by social media. The tourists make a lot of decisions with abundant scattered information.

This decision making process can be divided into three dimensions

1. Temporal: Ongoing search i.e. independent form specific decisions; versus Pre purchase search i.e. search to facilitate decision making.
2. Spacial: Internal search (based on long term memory) and External Search (focused on external information).
3. Operational: Contributory source versus Decisive source [4].

Every traveler undergoes the decision making process with a high cognitive load [5]. In this process tourists face issues while deciding the destination and the stay for the vacation with fragmented information, mixed reviews, low quality images [6]. Virtual reality has been considered a beneficial tool in surgical training due to the advantages—to create realistic images and is navigable in the environment [7]. Due to these peculiar characteristics of the virtual world it will be interesting to add the virtual reality technology in the planning process of the vacation.

This paper aims to incorporate virtual reality in the tourism industry to ease the decision making process. The objective of the paper is to understand the multi-stage process in tour planning in order to aid stress free and quicker travel planning. This paper also explores the different technologies which can help in planning the vacation and stay. It also focuses on how travelers perceive virtual reality and its acceptance in the tourism industry.

2 Literature Review

Vacations are something that everyone looks forward to. It allows an opportunity to unwind, disconnect, relax and rejuvenate. Vacation and travel may be solo or with family or friends but what makes them memorable is the freedom to create a customized experience [8]. Although it may seem that the concept of taking vacations is a recent phenomenon given the stresses of today's routine life, the need to get away goes back millennia. There is reliable documentation that shows that conquest formed one of the key reasons for travel. Although military forces often traveled great distances, it was probably not until the emergence of the Egyptian, Eastern Mediterranean, and Roman Empires that travel began to evolve into tourism as we know it today [9]. Apart from conquest, people also travelled for government work, commercial reasons. Ancient Romans were among the first civilizations known to travel and take vacations for pleasure [10]. But their vacations varied from a few weeks or could last as long as two years [11]. This freedom gave rise to establishment of lodging and restaurants and more catered infrastructure like tour guides and guidebooks. Pausanias 'Description *of Greece*, a very comprehensive insight into the region, was the earliest one of its kind and set a standard for what travel guides should be [12]. There was an intricate network of inns that offered lodging and food, and provided support and security to travelers. With the rise of Rome and Jerusalem in Christian Europe pilgrims started undertaking journeys from far off places. Matthew Paris 'Map of the Itinerary from London to Jerusalem published in the thirteenth century sheds light on the distances that pilgrims travelled [13]. Even with the Fall of Rome and the advent of the Dark Ages people travelling for pilgrimages did not abate. People who had the thirst for travel and curiosity often became part of merchant convoys that allowed them mostly safe passage. Breakthrough inventions like the automobile and the aero plane at the turn of the twentieth century would change the way people experienced travel forever.

The tourist is generally wary of the unknown [14]. Perhaps this element of fear and the limited time for leisure travel are the distinguishing factors that prompts the tourist to pre-plan and secure all the details of their vacation beforehand, as opposed to the traveler who is much more open to uncertainties along the way. Finances also play a role in planning vacations as the cost of travel by air is usually high and requires appropriate budgeting.

The cost of accommodation too forms a large chunk of travel expenses, second only to tickets and sometimes even overtaking those expenses. With the help of technology tourists are able to book tickets, accommodation and experiences online, however they need to sift through a plethora of information available at their fingertips before finalizing on the appropriate choices. Online reviews posted in travel related forums and rating websites increase traveler's confidence during decision making. Promotions and content generated by travel bloggers and influencers on social media further increase confidence through a community spirit fostered through storytelling and by travelers' shared interests [15]. However, this vast ocean of content can often end up seeming overwhelming and confusing to a traveler trying to make choices.

Tourists prefer getting a preview of the place they want to visit, before they make their decision. Hence, a lot of the content on these platforms are visual. Smaller tourism promoters lure customers by offering them real feel photos of the hotel, varying from photos of the place to 360° views where the customer can pan across and see the whole room from the comfort of their screens. This allows tourists to get a better understanding of the facilities that they are paying for. It also bodes well for these hotels to have such tools to entice prospective customers since it classifies them as a more premium establishment compared to those that do not.

Virtual reality being a popular concept in other areas such as Gaming, Aviation, Medical etc. Incorporation of the same in Travel is not surprising. Major hotel chains are looking to adopt Augmented Reality (AR) and more specifically Virtual Reality (VR) services. This allows their clients to experience a cabin on a cruise ship or be transported to an ancient wonder of the world. This trend is bound to become popular and we'll see more and more chains offer the same in the future. Tools like the Oculus Rift make virtual reality very accessible and takes it out of the domain of video game users and into a real world application with far reaching impact. Internet of Things (IoT) is another phenomenon that will create a significant impact on the tourist experience. There will be sensors in suitcases, hotel room locks, appliances in the room that can communicate with your device via the internet to let you be able to control them at your whim. Hotels will also be able to enlist the services of a Virtual Assistant or an e-Concierge that will cater to all the needs of the customer. This might be assisted further with the use of Recognition Technology. Both these technologies will help the hotel forge a relationship with the customer even before they set foot on the property. Slowly but surely travel companies might resort to Big Data and data analytics to ensure targeted marketing to get more customers. Proliferation of Cryptocurrency, Contactless Payment modes and Cybersecurity measures will ensure that the tourist had a highly convenient, hassle free and very memorable travel and stay experience.

3 Methodology

The data for the research was gathered using combination of qualitative and quantitative methodology. The data collection method was divided into 2 stages. First stage was sharing the survey to collect the quantitative data. The participants to fill the survey were randomly selected. The survey method was to identify frequent and infrequent travelers. The other objective of the survey was also to understand the way people search the information and face problems during the planning process.

Second stage of the data collection was the semi structured interview to collect the qualitative data. The participants selected for the interviews were a heterogeneous group of travelers irrespective of age and gender were selected from the first stage of research. The interviews were conducted face to face for few participants. Participants from different cities were approached by email, prior consent was taken and interview was recorded on mobile phone. The interviews were conducted to understand the how

people analyses a particular destination and the stay, how they compare the places to stay. The other objective was to pin point the difficulty faced while planning process. The other intention of the interview was also to understand people's perception and acceptance about the virtual reality incorporated in the planning process.

Out of 200 identified people 156 people responded to the survey. In the second stage of data collection out of 156 respondents 124 agreed to participate in the interview and 32 participants dropped out due to unavailability. All the participants were given former explanation about the research. Participants were also informed that the interview will be recorded. The data collected was analyzed qualitatively and quantitatively.

4 Results

The data collected was analyzed both quantitatively and qualitatively. The qualitative data collected was analyzed through Grounded theory approach [16]. The quantitative data was analyzed through the statistical analysis [17].

Travel frequency—Majority (43%) of people mentioned that they travel once in every year. Whereas 29% of people said they travel twice a year, 18% mentioned quarterly. Surprisingly 10% people mentioned they travel once in 2 years (Fig. 1).

People who travel once in two years were identified as infrequent travelers and were to considered for the interviews.

Factors influencing decision making—Almost 43% of travelers mentioned that destination is the key for the decision making hence which destination to go becomes the priority of the planning process. However, 32% people prioritized budget followed by 20% mentioning stay as the decision making factor. Few travelers 05% prioritize the food over destination budget and stay (Fig. 2).

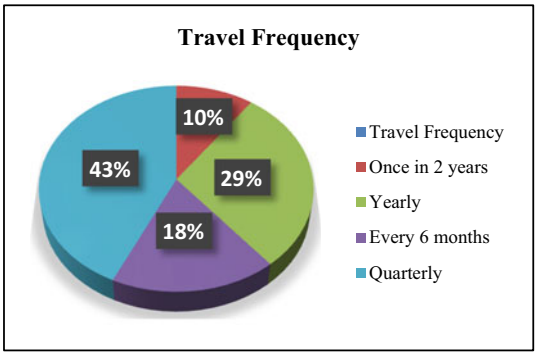

Fig. 1 How frequently you travel

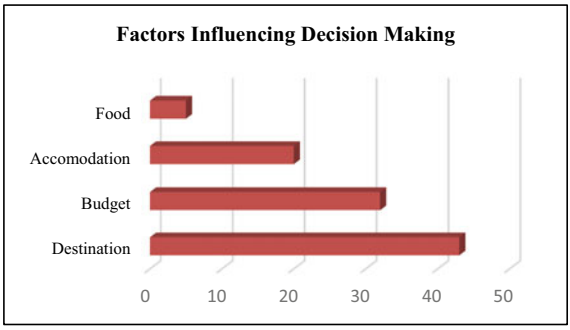

Fig. 2 Most important factor influences the decision while planning

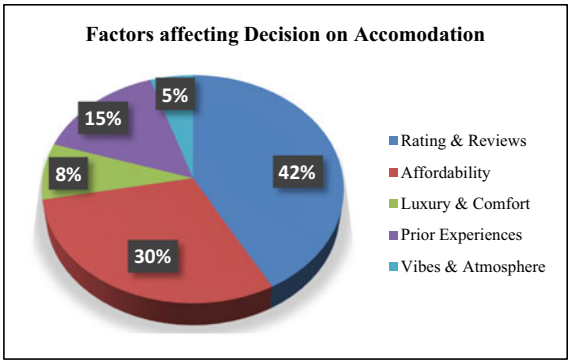

Fig. 3 Factors affecting decision on accommodation

Factors affecting decision on accommodation—42% of travelers rely on the ratings and review, which affects their decisions. 30% people check the affordability before confirming on a particular accommodation, followed by 08% who prioritize luxury and comfort. 15% of people prefer the same hospitality partners they have chosen earlier due to their prior experiences and 5% people believe in the vibe and atmosphere of the accommodation (Fig. 3).

Problems faced while deciding accommodation—26% people had issues with improper photos and lack of information. 23% of people get confused with mixed reviews and hence face issues with deciding the accommodation. Few travelers (31%) face problems as the desired accommodation went out of budget. 15% people face issues with non-availability of the accommodation. Interestingly 5% people gave other reasons such as travel taking time and hence face issues with accommodation (Fig. 4).

The qualitative data was divided into themes, Information collected during the planning process; Sense of Dissatisfaction in the accommodation; Perception and Acceptance of virtual reality.

Information collected during the planning process—The participants were classified into two major groups Online and Offline information collectors. 66% of people who

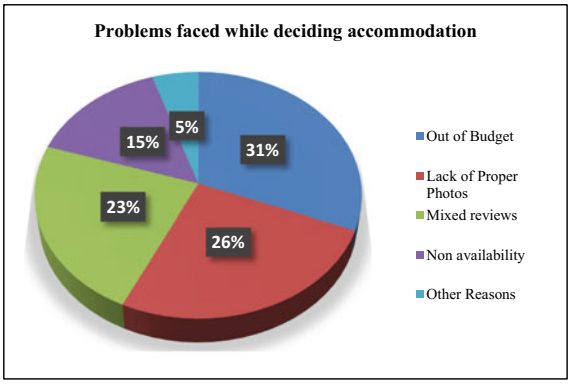

Fig. 4 Problems faced by travellers while deciding the accommodation

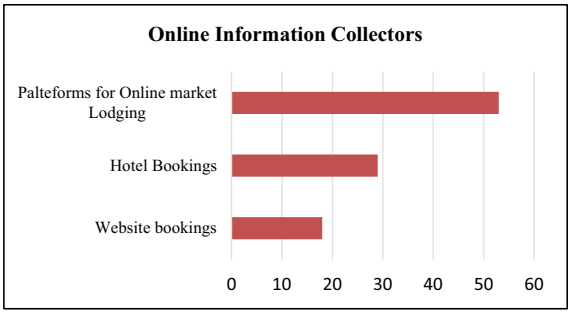

Fig. 5 Online information collectors

collected the information online were categories as—Online Information Collectors. Online information was more preferred by participants as they rely on photos, videos, 360° views. 34% of participants who collected the information offline were categorized as—Offline information collectors. Offline information was less preferred due to limited access to information. Participants rely either on Personal experience of that particular place or the recommendation from a friend or relative. Participants also contact the place of accommodation for further information about accommodation and the destination too.

Participants collected information through different modes which were later coded as—Websites booking whole travel, Hotel websites and—Platforms for online marketplace for lodging. Participants mentioned it was easy to book the whole trip through the—website which books whole travel as it is convenient as the company suggest the accommodations as per the plan. Few participants mentioned that it was easy to search for hotel or chains of hotels within the destination and book through—Hotel Website. These were majorly done as people trust few hotel chains and hence were sure about the accommodation and services (Fig. 5).

Participants also preferred the online platforms such as Airbnb due to variety of properties. It is easy because participants were able to choose the accommodation as per the cost, amenities etc.

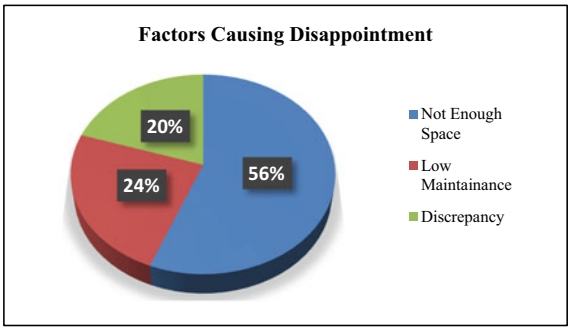

Fig. 6 Factors evoking the emotion of disappointment

Sense of dissatisfaction in the accommodation—Overall 56% of people are disappointed. Whereas 30% of people are rarely disappointed. Overall many travelers have a sense of disappointment in them. This disappointment can be due to various factors. Participant mentioned that many times the space in the accommodation is not enough as showed in the photos and the 360° views. The photos and walk through does not give the sense of the area which leads to dissatisfaction. Another major factor is the cleanliness and maintenance. The reviews mention that the place is clean and maintained but in reality it is not. The cleanliness and maintenance claimed by the hospitality group and the reviews does not match. The outdoor view from the hotel and the surrounding is not as shown while booking and check-in. The discrepancy between such factors evokes negative emotions in the traveller causing the disappointment (Fig. 6).

Immersive technology gives the idea of mood, feel and the area allocation within the environment. The participant feels that he/she is actually in the room and watching the surroundings. Participants were asked if they would prefer to see and experience the space in the virtual world and experience the accommodation, view and the environment. 45% of travelers were excited to have an immersive experience. Participants also correlated that it will be easy to relate the photographs shown and the actual space and size of the accommodation. They also mentioned the views and environment will increase the experience and excitement to visit the destination. 39% of the participants were neutral about the idea. Participants mentioned that they are not sure about the technology but can surely try the immersive experience. However, 16% of people were not able to relate to the idea and hence mentioned that they won't try the immersive technology. They also mentioned that it will kill the enthusiasm of the destination and accommodation (Fig. 7).

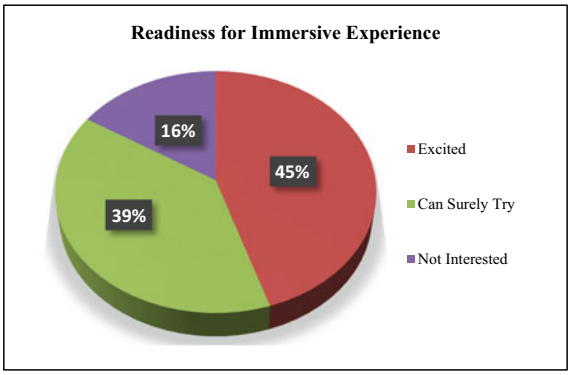

Fig. 7 Readiness for immersive experience

5 Conclusion

The research shows that travel planning employs a variety of technologically led means in the decision making process. Due to the oversaturation by visual content available online and disappointments faced in real life when basing trust on online content, it is imperative to bring in more advanced technology that can help reduce the cognitive load while making decisions and provide a more realistic basis to making travel choices. To this end, the study has clearly shown that VR is one such technology that people are familiar with and would be interested in engaging with.

The research has also shed light on the effects that high proliferation of technology will have on the tourism industry. Tourists will be equipped with all the information they need to make an informed decision and will be rest assured that this decision will not lead to disappointment. This will be ensured by the extensive back and forth communication the tourist will have with their personal 'e-Concierge regarding all the minute details of their trip and stay. But the highlight of the decision making process will be the ability to have experienced a small preview of the actual feeling of being present in the desired location of travel or stay courtesy a highly vivid and specifically tailored, immersive VR experience. These experiences in travel and tourism can bring the attributes of the destination and accommodation to the prospective traveler in a way that can be perceived by all their senses. This would help them to get a more cohesive experience of their choices before they book, enabling a more satisfying decision. With the way the industry is embracing all these advancements in technology and with tourists constantly looking for a custom designed experience, we are bound to see these applications become increasingly mainstream. Going through a VR experience to ensure you get what you are paying for will inevitably become the norm. This planning stage which till now was more of a behind the scenes step towards the actual vacation experience will become the first main step resulting in ample content for the tourist's social media handles even before the actual vacation starts. The readiness of people to accept the virtual world in their planning stage is sufficiently backed up with the above study. It also directs that the cognitive load

and the stress caused during the planning process will be markedly reduced. It will in turn help in decision making and will enhance the overall experience.

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Digitized Visual Fatigue Detection for Humanizing Digital Work Environments

Prerita Kalra and Vinod Karar

Abstract The recent outbreak of the COVID-19 pandemic has led to an increase in digital screen time. This extended screen time has led to an increase in visual fatigue levels in the users of digital information displays. Users of these displays tend to ignore the visual fatigue in the initial stages thus causing it to accumulate over time. A visual fatigue level beyond the circadian limit can lead to serious problems. In order to avoid the build-up of visual fatigue to such an extent, it is imperative that the visual fatigue level of the users is checked and managed at regular intervals. This research work was aimed at developing an easy to administer digital test for checking the visual fatigue level of the digital information display users. The decline in visual accommodation with increase in visual fatigue has been used as the basis for developing this test. The digital test has been calibrated against the readings from a standard visual fatigue test.

Keywords Visual fatigue · Visual accommodation · Digitized visual fatigue test · Digital work environments

1 Introduction

The lockdown measures introduced during the COVID-19 pandemic have led to an increase in digital screen time for students, working professionals as well as the general public [1]. The speed of adoption of digital technologies has taken a quantum leap because of the COVID-19 pandemic. Academic institutions as well as various industries have switched to using digital technologies for carrying out routine tasks. Consumers have flocked to online channels and a lot of industries and institutes have responded in return.

A recent study by McKinsey and Company found that the percentage of digital customer interactions has increased way more than it has in the pre-COVID years [2]. This can be seen from the graphs in Fig. 1.

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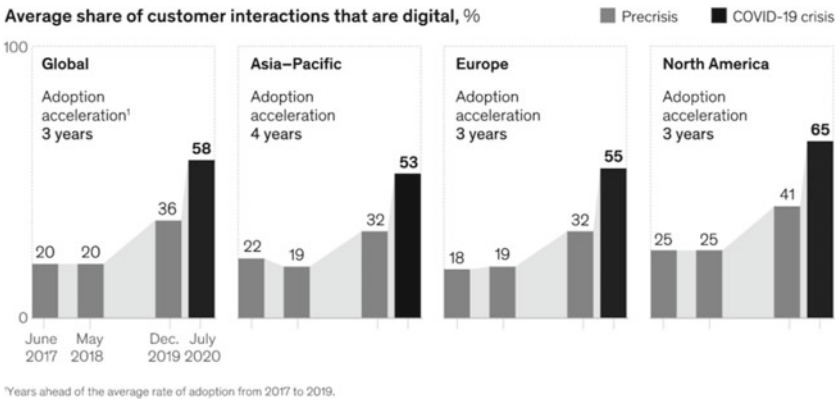

Fig. 1 Average share of digital customer interactions [2]

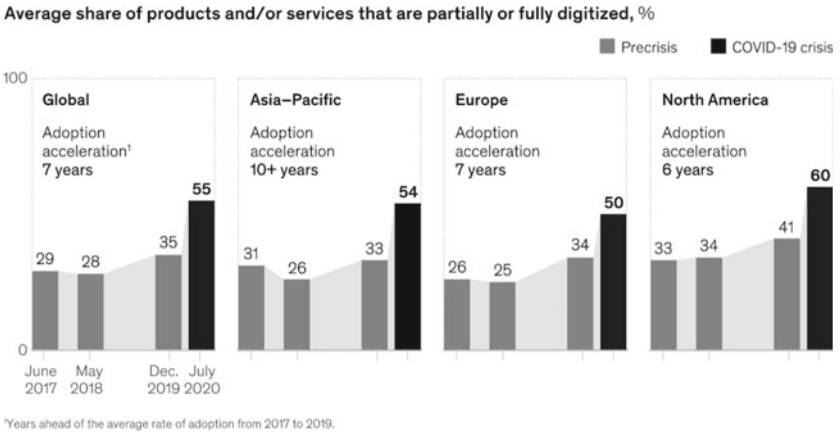

Fig. 2 Average share of digitized products/services [2]

The study also found that the companies and institutions have refocused their offerings leading to a massive increase in the number of digitized products/services in the post-COVID years. This can be seen from the graphs in Fig. 2.

This massive increase in interaction with digital products and services has led to an increase in digital screen time which in turn has led to an increase in visual fatigue levels in the users of digital information displays. Visual fatigue often goes undetected in the initial stages, which causes it to build-up over time, leading to serious problems. As of date, prevention is the key strategy for managing visual fatigue [3]. Thus, it is imperative that the visual fatigue level of the users is checked and managed at regular intervals in order to avoid the build-up of visual fatigue.

The existing methods to check the visual fatigue level, however, are either subjective- involving the use of questionnaires, or involve the use of equipment that may not be readily available with the digital information display users. This is a limitation in objective measurement of the visual fatigue level at regular intervals.

The objective of this research work was to develop an easy to administer digital test for objectively checking the visual fatigue level of the digital information display users.

2 Methods

2.1 Design of Digital Visual Fatigue Test

Continuous viewing of digital displays, which leads to visual fatigue, stiffens the ciliary muscles responsible for controlling the accommodation process. This leads to a decrease in visual acuity levels, where visual acuity refers to the visual system's ability to resolve detail. Thus, measuring the decline in visual acuity levels of the digital information display users can give a fair idea of the visual fatigue induced.

Using a conventional visual acuity chart for measuring the visual fatigue levels requires the visual acuity to be checked from a viewing distance of 6 m. Having this sort of a set-up is not always feasible for a person working on a digital information display.

Thus, a digitized visual acuity test scaled for 0.6 m, which is the recommended viewing distance for most digital information displays, was designed as a part of this research work. This eliminates the need for a physical visual acuity chart and also removes the requirement of placing the visual acuity chart at a distance of 6 m at regular intervals. This is extremely helpful in the scenario when a physical visual acuity chart can't be placed permanently at a distance of 6 m from the digital information display user.

The digitized visual acuity test was designed to be a logMAR (logarithm of the Minimum Angle of Resolution) visual acuity chart since logMAR visual acuity charts are widely recognized to be much more reliable than the Snellen visual acuity charts [4]. They also provide a much more discriminative visual acuity measurement compared to the Snellen visual acuity chart. The logMAR visual acuity charts have also been proposed as a standard for clinical research and trials of ophthalmic devices [5].

The logMAR visual acuity chart follows a logarithmic progression and the same number of test optotypes are shown for each optotype size [6]. The gap between each optotype in a line is equal to the width of the optotype in that line. The visual acuity, when using a logMAR chart, is calculated with reference to the log of the minimum angle of resolution as suggested by the name. Figure 3 shows the minimum angle of resolution for a Tumbling E optotype. The minimum angle of resolution is one-minute arc for a person with standard vision. This implies that a person with

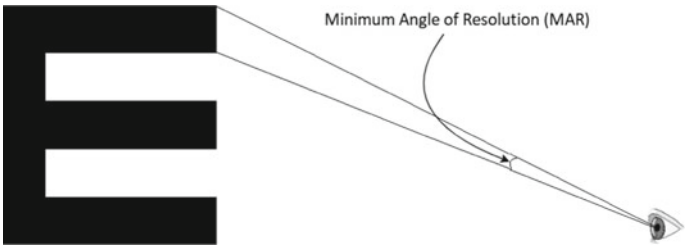

Fig. 3 Minimum angle of resolution (MAR)

standard vision can recognize two distinct points as long as they subtend a minimum angle of one-minute arc at the eye.

For a person with standard vision to be able to recognize an optotype, the optotype should subtend a minimum angle of five-minutes arc at the eye.

The relation between the logMAR and Snellen visual acuity scales is given by Eq. (1).

$$logMAR = \log\left(\frac{1}{Snellen's\ Fraction}\right) \tag{1}$$

where

$$Snellen's\ Fraction = \frac{\text{Distance at which test is carried out}(D_T)}{Distance\ at\ which\ the\ optotype\ subtends\ an\ angle\ of\ 5'arc(D_S)} \tag{2}$$

The optotype needs to subtend an angle of five-minutes arc at the eye at D_S, in order to be just recognized by a person with standard vision standing at a distance of D_S from it. Thus, the height of the optotype is given by Eq. (3).

$$\tan(5') = \frac{Optotype\ Height\ (H_O)}{Distance\ from\ the\ optotype\ to\ the\ eye\ (D_S)} \tag{3}$$

The logMAR values used for developing the digitized visual acuity test range from 1.00 to − 0.30. The equivalent Snellen's Fractions and the corresponding optotype dimensions have been calculated and are given in Table 1.

The digitized visual acuity test was designed to use the Tumbling E optotype i.e. the letter E in various orientations. This optotype was chosen since previous studies have shown that the visual acuity threshold for the Tumbling E is slightly better than that for the Landolt C which is considered to be a research standard by The International Council of Ophthalmology [7, 8].

The Tumbling E optotype corresponding to the logMAR visual acuity 1 is shown in Fig. 4. The following paragraphs show the calculations for the design of the same.

Table 1 logMAR values and corresponding optotype dimensions used for developing the visual acuity test

Visual acuity (logMAR)	Equivalent Snellen's fraction	Optotype height (H_O) (in cm)	Thickness of critical detail ($T_{CD} = H_O/5$) (in cm)
1.00	0.6/6	0.87	0.174
0.90	0.6/4.8	0.696	0.1392
0.80	0.6/3.8	0.551	0.1102
0.70	0.6/3	0.435	0.087
0.60	0.6/2.4	0.348	0.0696
0.50	0.6/1.9	0.2755	0.0551
0.40	0.6/1.5	0.2175	0.0435
0.30	0.6/1.2	0.174	0.0348
0.20	0.6/0.95	0.13775	0.02755
0.10	0.6/0.75	0.10875	0.02175
0.00	0.6/0.6	0.087	0.0174
−0.10	0.6/0.48	0.0696	0.01392
−0.20	0.6/0.38	0.0551	0.01102
−0.30	0.6/0.3	0.0435	0.0087

Fig. 4 Tumbling E optotype corresponding to logMAR visual acuity 1

The equivalent Snellen's Fraction for the test to be conducted at 0.6 m i.e. $D_T = 0.6$ is calculated as:

$$Snellen's\ Fraction = \frac{1}{\log^{-1}(logMAR)} = \frac{1}{\log^{-1}(1)} = \frac{1}{10} \qquad \text{(using 1)}$$

The distance at which this optotype subtends an angle of five-minutes arc, D_S is calculated as:

$$D_S = \frac{D_T}{Snellen's\ Fraction} = \frac{0.6}{1/10} = 6 \qquad \text{(using 2)}$$

Since the Tumbling E optotype should subtend an angle of five-minutes arc at the eye at $D_S = 6$, to be just visible to a person with standard vision, the height of the optotype is calculated as:

$$Optotype\ Height(H_O) = \tan(5') * D_S = \tan(5') * 6 = 0.87\ \text{cm} \qquad \text{(using 3)}$$

The thickness of critical detail for the optotype, since it should subtend an angle of one-minute arc at the eye at $D_S = 6$ to be just visible to a person with standard vision, is calculated as:

$$Thickness\ of\ Critical\ Detail(T_{CD}) = \frac{H_O}{5} = 0.174\ \text{cm}$$

For checking the visual fatigue level of a user, five Tumbling Es corresponding to logMAR visual acuity 1 are shown to the user in a single line. The spacing between the Tumbling Es is kept equal to the width of the optotype. The user is asked to identify the orientation of all the Tumbling Es in the given line. If the user identifies the orientation of three or more Tumbling Es correctly, five Tumbling Es with a logMAR visual acuity decreased by 0.1 are subsequently shown to the user. The logMAR visual acuity of the five Tumbling Es shown to the user is decreased by 0.1 until the user fails to recognize the orientation of at least three Tumbling Es in a given line. The lowest logMAR visual acuity line shown to the user was used to define the logMAR Score for the user, the formula of which is given by Eq. (4).

$$\begin{aligned} logMAR\ Score = {} & 0.1 + lowest\ logMAR\ visual\ acuity\ shown\ to\ the\ user \\ & - 0.02 * (number\ of\ optotypes\ recognized\ correctly \\ & in\ the\ last\ line\ shown) \end{aligned} \tag{4}$$

Since each line has five optotypes, the formula can be rewritten as:

$$\begin{aligned} logMAR\ Score &= 0.1 + lowest\ logMAR\ visual\ acuity\ shown\ to\ the\ user \\ &\quad - 0.02 * (5 - number\ of\ optotypes\ recognized\ erroneously \\ &\quad in\ the\ last\ line\ shown) \\ &= lowest\ logMAR\ visual\ acuity\ shown\ to\ the\ user \\ &\quad + 0.02 * (number\ of\ optotypes\ recognized\ erroneously \\ &\quad in\ the\ last\ line\ shown) \end{aligned} \tag{5}$$

2.2 Participants

This proposed method was tested with the help of forty participants in the age range of 20–65 (mean age = 38.98). The minimum number of participants required to get a desired margin of error was calculated using Eq. (6).

$$n \geq \left(\frac{z^* * Standard\ Deviation\ (\sigma)}{Margin\ of\ Error\ (MOE)} \right)^2 \tag{6}$$

where z* value was taken as 2.33 corresponding to 98% confidence level.

It was ensured that the visual acuity of the participants was normal or corrected to normal. All the participants had enthusiastically volunteered to be a part of this study as they acknowledged the need for such a study in the wake of increased screen times during the ongoing COVID-19 pandemic. No idea about the expected outcomes of the experiment, however, was given to the participants prior to the experiment.

2.3 Workstation and Surroundings

Taking the current COVID-19 situation into consideration, the participants were made to take part in the study from their respective homes. Guidelines, to ensure an ergonomic work environment, were shared with the participants a day before the study was conducted. These guidelines were developed in accordance with previous research studies [9–13]. The participants were asked to sit in a well illuminated room for the experiment with their laptop's brightness set at a value of around 110 cd/m^2. They were told to maintain a viewing angle below the eye level and a viewing distance of roughly 0.6 m from the laptop during the experiment.

2.4 Experiment Design

The participants were asked to perform simple web development tasks of 2.5 hours duration. Their visual fatigue level was measured before and after the task was completed. The visual fatigue level was measured using the developed digital visual fatigue test and also using a modified version of the questionnaire developed by Ames et al. [14]. The questionnaire consisted of ten symptoms associated with Asthenopia, the level of which was to be marked on a scale graded from 0 to 6. The value 6 denoted the highest severity of that symptom while 0 denoted its absence. The questionnaire is given in Table 2. The visual fatigue score, representing the visual fatigue induced during the task, was calculated using the difference of visual fatigue levels recorded before and after the task.

2.5 Statistical Analysis

The statistical analysis was carried out using IBM® SPSS Version 23. Spearman's Rank-Order Correlation was used to determine the correlation between the visual fatigue score recorded using the developed digital visual fatigue test and the score recorded using the Asthenopia Questionnaire.

Table 2 Asthenopia Questionnaire [14]

Symptom	None	Slight		Moderate		Severe	
Tired eye	0	1	2	3	4	5	6
Sore/Aching eye	0	1	2	3	4	5	6
Irritated eye	0	1	2	3	4	5	6
Watery eye	0	1	2	3	4	5	6
Dry eye	0	1	2	3	4	5	6
Eye strain	0	1	2	3	4	5	6
Hot/Burning eye	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Difficulty in focusing	0	1	2	3	4	5	6
Visual discomfort	0	1	2	3	4	5	6

Table 3 Descriptives of visual fatigue scores recorded using different methods

	N	Minimum	Maximum	Mean	Std. deviation
Visual fatigue scores using digital visual fatigue test	40	0.02	0.16	0.0640	0.04005
Visual fatigue scores using Asthenopia Questionnaire	40	1.00	9.00	4.8000	2.53387

3 Results and Discussion

3.1 Descriptives of Recorded Visual Fatigue Scores

The descriptive statistics—minimum, maximum, mean and standard deviation for the visual fatigue scores recorded using the digital visual fatigue test and the visual fatigue scores recorded using the Asthenopia Questionnaire are given in Table 3.

3.2 Correlation Between Visual Fatigue Scores Recorded Using Proposed and Existing Methods

The Spearman's Rank-Order Correlation showed a strong, positive correlation between the visual fatigue scores recorded using the digital visual fatigue test and the visual fatigue scores recorded using the Asthenopia Questionnaire. The correlation was statistically significant ($r_s = 0.864, p < 0.001$). The results for the same are given in Table 4.

Since the visual fatigue scores recorded using the digital visual fatigue test showed a strong positive correlation with the visual fatigue scores recorded using

Table 4 Spearman's rank-order correlation between visual fatigue scores recorded using the digital visual fatigue test and the visual fatigue scores recorded using the Asthenopia Questionnaire

			Visual fatigue scores using digital visual fatigue test	Visual fatigue scores using Asthenopia Questionnaire
Spearman's rho	Visual fatigue scores using digital visual fatigue test	Correlation coefficient	1.000	0.864**
		Sig. (2-tailed)		0.000
		N	40	40
	Visual fatigue scores using Asthenopia Questionnaire	Correlation coefficient	0.864**	1.000
		Sig. (2-tailed)	0.000	
		N	40	40

**Correlation is significant at the 0.01 level (2-tailed)

the Asthenopia Questionnaire, the developed digital visual fatigue test can be used by the users of digital information displays to objectively self-monitor and manage their visual fatigue levels in time. This digital visual fatigue test has an advantage over existing objective measures of visual fatigue since it does not involve the use of bulky and expensive equipment. The objective indicators of visual fatigue used by researchers in the past include critical fusion frequency, pupil constriction rate and eye blink rate [15–17]. Objective metrics based on bio signals such as electroencephalogram (EEG), electrocardiogram (ECG), electrooculogram (EOG), photoplethysmogram (PPG), galvanic skin response (GSR) and skin temperature (SKT) have also been tried by researchers to measure visual fatigue [18–22]. The existing objective measures of visual fatigue require controlled environments and complex operational procedures making them difficult to use for a common digital information display user. The developed digital visual fatigue test is relatively simple to use and will thus help the digital information display users to self-monitor their visual fatigue levels at regular intervals.

Given the current scenario, when the use of digital information displays has increased manifold, it is important that the users of these displays follow ergonomic practices while using these displays. These ergonomic practices include maintaining a proper viewing distance in accordance to the size of the digital display, maintaining a viewing angle fifteen to twenty degrees below the eye level, setting the screen brightness level at an optimal value in accordance with the ambient lighting and setting the resolution of the digital information display screen in accordance with the size of the digital display. Following these ergonomic practices along with regular monitoring of visual fatigue levels using the developed digital visual fatigue test will help the users of these digital displays manage their visual fatigue levels in time.

4 Conclusion

An easy to administer digital visual fatigue test was developed as a part of this study to enable the users of digital information displays to objectively self-monitor their visual fatigue levels and manage it in time. The developed digital visual fatigue test's scores showed a strong positive correlation with the visual fatigue scores recorded using the Asthenopia Questionnaire, thus validating the scores of the digital visual fatigue test as a measure of visual fatigue. A high score on this digital visual fatigue test represents a high level of visual fatigue which calls for timely visual fatigue management in order to prevent build-up of visual fatigue beyond circadian limits.

This test would help the digital information display users to monitor their visual fatigue levels at regular intervals without user subjectivity and without bulky equipment. It would be instrumental in ensuring that the visual fatigue level of the users of digital information displays is kept under control especially during the current times when the use of laptops, mobiles, and AR and VR devices has increased manifold.

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Preliminary Survey in FMCG Shop-Floors to Understand Operational Activities for Identifying Ergonomic Stressors: A Case Study from North-East India

Gurdeep Singh and Sougata Karmakar

Abstract Fast Moving Consumer Goods (FMCG) industries dwelling on high-paced assembly-lines and highly-repetitive short-cycled work producing high volume-low cost products under Just In Time (JIT) production process contributes a lot to every country's Gross Domestic Product (GDP) and employment generation. Supported by various government schemes and initiatives, the FMCG industries flourish throughout India, and north-east India is a prominent hub for FMCG business houses. Traditionally, the FMCG manufacturing units built upon the pre-defined plot sizes provided in industrial parks lack the thorough consideration of ergonomic aspects within facility layout planning and other machinery installation early from the commissioning phase. It affects productivity and leads to other Occupational Health and Safety (OHS) issues. Considering the FMCG industries' significant role in the Indian economy and society, the researchers conducted an in-depth survey of the FMCG industries (located in north-east India) to understand the operational activities and identify ergonomic stressors which hampers the overall productivity and safety. During the field visits and survey, it was observed that there is an immediate need for thorough ergonomic consideration in implemented Kaizens, standardization of work activities, and implementation of context-specific tools for the FMCG work. Detailed ergonomic studies are further required to propose context-specific ergonomic interventions, which may be behavioral, organizational, or design-related. Such interventions will prove beneficial for promoting better OSH and thereby improved efficiency and productivity.

Keywords Ergo-audit · Industrial shop-floor · Kaizen · Lean manufacturing · WMSDs · OSH · Safety · User-centered design

1 Introduction

Fast Moving Consumer Goods (FMCG) or groceries are of utmost concern for daily need consumption all around the world [1]. The FMCG sector is highly

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important for all countries, and it provides great strength to any nation's Gross Domestic Product (GDP) and employment scenario [2, 3]. It is alternatively known as the 'make and pack' industry as it involves making food items, personal care products, over-the-counter drugs, etc., on high-paced parallelly arranged assembly-lines and then packing those in aesthetically designed packaging [4]. The FMCG assembly-line activities involve micro-motion-based short-cycled highly-repetitive finger, wrist, and upper extremity movements. Assembly-line activities in varied industrial sectors are prone to Musculoskeletal Diseases (MSDs), drudgery, and various other Occupational Safety and Health (OSH) issues [5, 6]. It always remains a concern for researchers, ergonomists, and safety activists. In India, the FMCG sector is widespread and engages more than 3 million people in employment [7]. The majority of Indian FMCG manufacturing is focused on personal care products, viz. shampoo, hair oil, detergents, cosmetics, etc. These are produced in every nook and corner of India. Several government schemes promote the spread of the FMCG manufacturing units to tier II or tier III cities of India [8]. In north-east India especially, the advent of these FMCG manufacturing units is a major boon to employment opportunities in these regions. The central government and the state government had developed several Industrial Parks (IPs) to set up the FMCG manufacturing units in this region [9]. In these IPs' pre-allotted space, these FMCG units have commissioned their machinery and carry on their production [10]. Ergonomics—the science of man–machine compatibility often lacks in such manufacturing set-up and leads to several ergonomic stressors and OSH issues [11, 12]. Considering the vast potential of the FMCG sector in GDP growth and employment generation in North-east India and the virgin stage of these industries in this region, it is the right time to identify any lacunae occurring in these industries from an ergonomic perspective. Early detection of ergonomic stressors and other production bottlenecks may prove beneficial for these industries and region as a whole. In this context, the researchers have planned and conducted an in-depth survey of the FMCG industries (located in north-east India) to understand the operational activities and identify ergonomic stressors which hampers the overall productivity and safety. It addressed the following research questions (a) What type of ergonomic stressors and bottlenecks to productivity prevail in the FMCG manufacturing units in the north-east? (b) Which are the areas of concern, and what interventions can act as probable mitigating solutions to improve the situations thereof? Thus, this paper can act as a ready reckoner for any researcher, engineer, and safety person looking to conduct ergonomic studies and investigations in the FMCG manufacturing units for OSH and productivity improvement.

2 Methodology

Preliminary, the data regarding the industries working in the FMCG sector within north-east India was gathered from various government records and reports published in Gazettes and available on government websites [9]. It was found that the government allotted several major FMCG industries space in IPs spread across Guwahati,

Sonitpur, Tinsukia, Nalbari, and other areas. Guwahati city is the prominent hub of such FMCG manufacturing units. Brahmaputra Industrial Park (BIP), Export Promotion Industrial Park (EPIP), Bamboo Technology Park (BTP), and Tea Park (TP) are prominent IPs established by the government in Guwahati [10]. The noticeable FMCG units located within IPs across the north-east region were approached. Formal permission to conduct an ergonomic survey to understand peculiar FMCG work activities to identify ergonomic stressors and other bottlenecks to productivity was sought. Formal permissions were obtained from several prominent FMCGs, and Non-disclosure Agreements (NDAs) were signed with factory management. Such FMCG industries had several manufacturing units spread across the entire north-eastern region within various IPs. These manufacturing units were engaged in manufacturing personal care products (cosmetics, shampoo, hair dye, hair oil, etc.). Regular visits in each manufacturing unit once a week were carried out for nine months, and production operations engaged were minutely observed, and photographic, and video evidence was collected. Field observations focused on understanding the critical parameters of FMCG. International Labor Organization (ILO) checklists [13] were followed to conduct ergo-audit at FMCG shop-floors. All the data gathered about FMCG shop-floor activities through ergo-audit and field observations were scrutinized to identify prevailing ergonomic stressors and operational bottlenecks to productivity.

3 Observations

Field observations at FMCG manufacturing units located in north-east India revealed the prevalence of several ergonomic stressors and productivity bottlenecks. These are discussed in the following sub-sections.

3.1 Awkward Postures

Prima Facie lots of work instances spread across various FMCG workstations indicated the adoption of awkward postures. Workers tend to adopt awkward posture to carry on their routine activities on their workstations. These situations prevailed almost in all manufacturing units under observation. It was observed that workers were working at shoulder height, colliding with machine parts while sitting on workstations, excessive bending, etc. Figure 1a–c depicts some of such instances where workers are exposed to awkward postures. Prolonged standing work posture for a time period ranging from 8 to 12 h was common among all assembly-line-related work activities. Short-cycled highly-repetitive work is highly prevalent on such assembly-lines and required fine finger movements and wrist involvement. The quality inspection workstations required high visual and cognitive requirements.

Fig. 1 **a** Working at shoulder height (awkward position). **b** Awkward seating (no lateral clearance, no foot rest). **c** Awkward bending (prolonged standing, high force)

3.2 Ill-Equipped Workstations/Inadequate Tools

Inadequate workstations were witnessed on FMCG shop-floors, and workers adjusted themselves on available workstations to perform their respective jobs. Improper furniture (stools, benches, chairs, etc.) exists at such workstations. These are generally in-house fabricated and lack the basic features (lumbar support, arm support, footrests, etc.) required for performing prolonged work activities efficiently. Figure 2a–c depicts a few such ill-equipped workstations.

Besides, inadequate tools exist for several key work activities, and workers tend to use and adapt to jugaad tools. In haste to perform their duties effectively, they often resort to using inadequate/inappropriate and sharp tools, which leads to injuries. Figure 3a illustrates the use of a sharp cutter blade, and Fig. 3b depicts the use of improper/inadequate tools to collect oil from the wet slippery floor. Factory management is, however, concerned about such issues and tries to refrain from the use of such tools and seeks context-specific solutions in this regard.

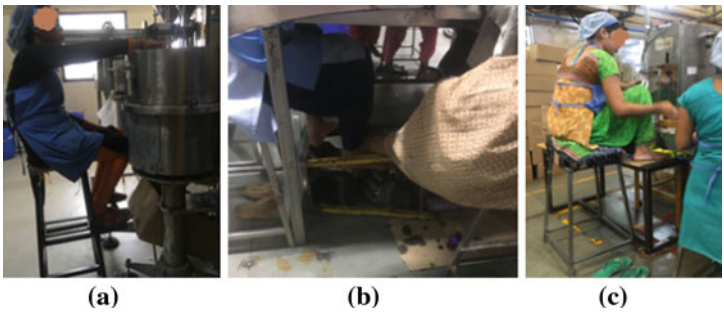

Fig. 2 **a** Working at height (no lumbar support). b Awkward seating (no foot rests). **c** Ill-equipped workstation

Fig. 3 **a** Sharp cutter blades being used. **b** Inadequate tool for floor cleaning

3.3 Improper Kaizens Implemented

The FMCG units are focused on implementing lean manufacturing principles into their operations. Kaizen (continuous improvement activities) are implemented on a routine basis in various FMCG operations and at different workstations. These primarily include in-house fabricated workbenches, furniture, work accessories, small jigs, and fixtures, etc. It was observed that although the Kaizens are being implemented, they are not much effective. Instead of improving productivity, they hamper it by leading to several ergonomic stressors. Figure 4a illustrates in-house workbenches developed under Kaizen activity. These workbenches are unable to cater to the anthropometric needs of the working population using these. They have to alter these as per their convenience using jugaad techniques like paper packing to raise the height in this case.

At critical workstations, e.g., bottle feeding station, to cater to the need of holding empty bottles to load on the high-paced assembly-line, additional holding trays are provided under Kaizen activity. These trays are attached to the standardized assembly-line. They act well for holding the material but compels the worker to work too away from the assembly-line and leads to awkward postures (Fig. 4b). It induces enhanced fatigue as workers working away from the assembly-line stretch their upper extremities to reach the work zone. Insufficient lateral clearance due to

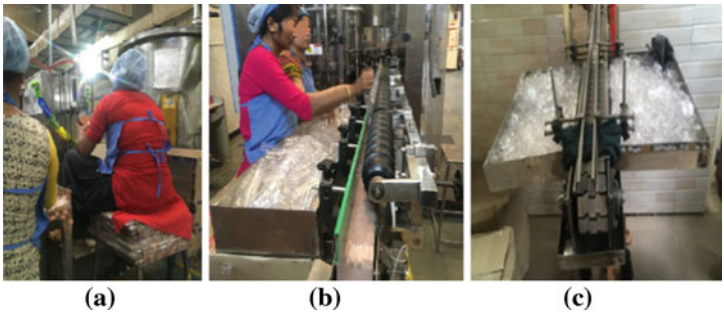

Fig. 4 **a** Paper packing inserted to raise seating height. **b** Bottle holding tray (no lateral clearance). **c** Bottle holding tray (for both side working)

Fig. 5 **a** Intermediate kaizen implemented (thin steel guide). **b** Material getting choked (next station is still slow)

these extended trays restricts the free space between worker body and work accessory. In such a situation, the worker tends to lean and collide with the tray. It results in off-balancing the assembly-line, and often, the vibrations from the machine-part oriented assembly-line are transferred to the worker body. In-house fabricated material handling trays for both side working stations across assembly-line is depicted in Fig. 4c. It poses the same problems to the workers working at these workstations.

At several workstations, impartial Kaizens are implemented haphazardly at intermediate positions without having thorough consideration of their effect on the previous and next workstation. Figure 5a, b illustrates one such example. In this situation, the implemented Kaizen is capable of enhancing the speed of work at the implemented workstation. However, the next workstation is not improved yet, and it is unable to handle the increased capacity/flow rate of products delivered from the previous workstation. As a result, the assembly-line gets choked, and further problems aggravate.

3.4 Non-standardized Work Practices

Having understood the peculiar work parameters of FMCG assembly-lines during the field observation, it was noticed that workstations spread across both sides of installed assembly-lines. Similarly, the additional work accessories were placed/provided at both left-hand and right-hand positions of the worker's seating arrangement. In order to match the man–machine ratio and pacing of high-speed assembly-line, additional workers are added to the existing assembly-line. Few of the identical workstations are on the right side of the assembly-line, and the rest are located on the other side. It was observed that principles of motion economy act as a boon for workstations located on one side of the assembly-line, whereas the other side suffered (lower productivity) due to their location against the material flow. Several such instances were observed. Figure 6 depicts one such scenario from the carton packing station.

Here, in this case, four different workers are engaged in carton filling, and their job seems to be identical. Material flow (filled bottles) is proceeding towards them at a high pace of the order 140–160 bottles per minute. In spite of four workers engaged, the assembly-line still chokes as they are not available to clear the assembly-line at the required rate. By conducting a time-motion study of this group activity, it was

Fig. 6 Non-synchronized carton filling activity

observed that the workers on the right side were able to perform the work quickly, and workers on the left were far behind. In addition, the worker working in the direction of material flow (worker A) was the most efficient among all. In this condition, worker A and worker C had completed their task, they are ideal now as worker B and worker D have not completed their carton filling yet. They are not able to pass on their filled cartons to the next station, and the overall productivity hampers. Such non-standardized work activities resulting from the un-planned spatial arrangement of workstations are commonly observed on FMCG shop-floors.

3.5 Unsafe Work Activities

The FMCG shop-floor activities involve some critical work activities that differentiate these from other manufacturing units. Such exclusive work activities are often carried out in an unorganized manner and lack specialized context-specific tools and workstations. One such activity is the re-working of defective liquid-filled pouches/sachets. It is carried out in almost every FMCG manufacturing unit and is a very voluminous work activity. In order to recover liquid out of damaged pouches/sachets, the workers cut the pouches/sachets with sharp cutters/blades/scissors while working bare hands. Manual hand squeezing of the cut pouches to drain the liquid is prevalent, spoiling their hands and leading to contamination of liquid being extracted. Figure 7a, b depict two scenarios of this activity. It is evident that no standardized workstation and tool exists for this activity. Cuts and injuries are common in such activity and are a significant concern for factory management. They seek an immediate solution for eliminating the use of sharp cutter/blades and standard workstation for this prominent re-work activity.

Fig. 7 **a** Sitting-position based pouch cutting activity (re-work). **b** Standing-position based pouch cutting activity (re-work)

3.6 Unplanned Facility Layout Planning

The majority of these FMCG units are built upon industrial plots allotted by the government within IPs. Raw material storage units, main production area, warehouse, etc., have been managed within the allotted space only. Thorough ergonomic considerations have been ignored while commissioning the machinery at the inception. Improper layout for inventory area, work in progress, and finished goods are prevalent across the manufacturing units. Upon gradual development of the manufacturing units within few years of inception, the need for expansion had occurred. To cater to this need, haphazard extensions have been done within the existing workspace. This leads to narrow passages, congested working areas, untidy workplace, unorganized production area, etc. It hampers the overall productivity of the manufacturing units.

3.7 Workshift Duration

Prolonged working hours exit within these FMCG manufacturing units. These manufacturing units work round the clock for twenty-four hours within shifts of 12 and 8 h. The majority of these manufacturing units have two shifts of 12-h, and only a few have three shifts of 8-h. The female staff works in the general shift (daytime), and the male staff works during the night shift too. As it is a 'make and pack' industry, a large number of the contractual workforce engaged in packing activities is common in these manufacturing units. Generally, this contractual workforce is unskilled and untrained.

3.8 Environmental Aspects

FMCG products constitute several chemical combinations within their products viz. cosmetic products, detergents, shampoo, hair oil, etc. The use of menthol is prevalent too. Maintenance of Indoor Air Quality (IAQ), airflow, ventilation, ambient temperature, humidity, etc., is the area of concern within these manufacturing units. The

final packing of the products is carried out using shrink packaging with heat ovens that generate lots of heat upon the production floor. Management of this heat dissipated is a major concern among the factory management. Several FMCG product like vaseline requires a cold environment, and it has to be managed accordingly.

4 Discussion

During the frequent visits upon selected FMCG manufacturing units, several important observations related to their working and work environment were noticed and have been discussed above. A brief discussion focusing upon the probable root cause of these problematic areas is being presented in this section.

4.1 Anthropometric Mismatch

Awkward posture adoption in such industries results from an anthropometric mismatch between the worker population and workstations/work accessories [14]. Thorough consideration towards body dimensions, range of motion, biomechanical parameters, etc., for devising appropriate workstations and accessories may help to curb the situation. Several researchers have taken such approaches in other manufacturing industries and helped to better the situation [14–16]. MSD prevalence and other associated OSH risks must be monitored regularly to curtail these in the early stages.

4.2 Ergonomic Principles and Design Strategies

Ignorance towards ergonomics—science of man–machine compatibility and ergonomic principles is common among workers and management in these industries. Continuous improvement activities (Kaizens) are being implemented without thorough consideration of ergonomic principles to develop in-house fabricated workstations and work accessories, leading to MSDs and other ergonomic stressors. Proper design strategies need to be implemented in conjunction with ergonomic principles to improve the situation [11].

4.3 Holistic Approach for Kaizens

In haste to efficiently run daily routine affairs, the factory management and supervisors resort to implementing Kaizens in a haphazard manner. Often these are related

to production/operational aspects that are productivity enhancement measures and ignore human elements [17, 18]. A holistic approach needs to be considered when any Kaizen has to be implemented. These must be applied with consultation among various stakeholder departments (production, operation, quality, safety) and must not be applied in a fragmented manner. The effects of any Kaizen implemented must be thoroughly assessed in advance, keeping in view the whole assembly-line as one unit.

4.4 Work Standardization

Specifically to FMCG assembly-lines, there lies the need to understand the optimum position for placing workstation and workstation accessories across the assembly-line. The spatial arrangement of these needs to be determined properly to ensure that principles of motion economy are harnessed efficiently. As such, work standardization techniques may act handy in such industries as implemented by other researchers within other industrial sectors [19, 20]. Design of experiments among such group tasks to better assess the situations and determine the best spatial orientation of workers may prove beneficial.

4.5 Innovative Tools and Strict Safety Policies

Context-specific work and work activities remain an integral part of any manufacturing unit, and FMCG is no exception to that. Re-work activities are one such activity on the FMCG shop floor. These must be understood carefully, considering all the work elements involved to assess the specific needs of such jobs. Further, based on these needs, innovative context-specific design interventions must be deployed to ensure safety and productivity among such tasks [11]. Strict safety protocols and training for workers in this context must be chalked out, implemented, and regularly monitored for its implementation.

4.6 Workplace Design and Space Management

Organized shop-floor layouts as per specific needs are essential for any industrial unit. Researchers have done a lot to improve shop-floor in various industrial set-ups [20–22]. Similar approaches must be considered at FMCG units as per the need for FMCG work parameters to better the situations. Handling and storing of raw material like lighter material, empty bottles, wrapping papers, etc., may be integrated vertically instead of spreading it horizontally to manage the space well. Similarly, the warehouse for storing finished goods may be efficiently managed. Efficient principles

of shop-floor layout, facility location planning must be integrated with supply chain and logistic principles in FMCG units that specifically dwell on the success of the material movement [23, 24].

4.7 Organizational Ergonomics

Organizational ergonomics principles benefit organizations a lot. These FMCG units must consider these principles to benefit. Workshift duration, job rotation, job enrichment, job enlargement, etc., might be applied in various departments, considering the required work parameters and efficiency [25, 26]. It will help to keep workers and managers more efficient and productive. Work training and welfare activities for temporary and unskilled workers will also prove beneficial and must not be taken as an extra burden by the management. It will help them build a reserve pool of effective workers in need and emergency [27].

4.8 Environment Monitoring

Regular and routine monitoring of existing environmental factors within an industrial unit is highly important to retain the manufacturing unit healthy, safe, and congenial for carrying out ongoing work activities [27, 28]. The FMCG units must have their own modern advanced apparatus for monitoring several environmental factors, and routine in-house audits must be carried out periodically by trained staff/team. Specialized audits for various environmental factors may be carried at fixed intervals by external agencies, and their suggestions must adhere [29, 30]. Context-specific needs of FMCG product manufacturing may be consulted, brainstormed, and innovative design interventions suitable as according to distinct needs may be implemented.

5 Scope for Improvement

As observed upon the FMCG manufacturing shop-floor, several cases have been discussed in the above section for the probable root cause, previously taken approaches by various researchers in diverse industrial sectors, and probable need and requirement of implementing those in the FMCG sector. There lies a scope of improvement of shop-floor activities within the FMCG units by means of ergonomic interventions that may be behavioral, organizational, or design-related. These can be categorized into the following broad categories.

5.1 Ergonomic Principles and Kaizen Implementation

The anthropometric and biomechanical characteristics of the working population of north-east India need to be considered while commissioning and installing the industrial set-up in this part of the country. Further, while devising Kaizen activities, thorough consideration of ergonomic principles must be taken into account for their successful implementation. Evaluation of MSDs due to the original set-up of workstations and implemented Kaizens should be rigorously done to assess the root causes and propose design interventions. Kaizen's thorough implementation by considering all production, operation, safety, ergonomic, and work standardized principles is the key to success. Fragmented approaches will result in failures only.

5.2 Work Standardization as Per FMCG Work Parameters

Imitation of lean principles into the FMCG manufacturing without considering its pros and cons regarding specific work parameters of the FMCG jobs is inappropriate and may create problems. Identification of appropriate work standardization techniques suitable for the FMCG jobs is required. There lies a need to determine the optimum level of man–machine deployment, pacing, spatial arrangement of workstations across assembly-line, etc. In this regard, a proper understanding of FMCG work parameters is required, and proper ergonomic and work standardization tools must be identified to propose interventions for improvement.

5.3 Innovative Tools

Peculiar work activities of the FMCG sector need thorough attention, and there is a need for developing context-specific innovative tools for such activities. These tools can ensure safety in the FMCG work activities and can reduce drudgery too. These tools must be cost-effective and economically viable. Re-work activity, housekeeping of wet slippery floors, oven-based shrink packaging, etc., are the most peculiar activities on the FMCG shop floors, which need immediate attention and demand design interventions based on ergonomic principles. Sincere efforts in this direction will improve the current safety concerns and will help workers and management.

6 Conclusion

The highlighted areas of concern described in the above section need thorough investigations from an ergonomics perspective and need immediate attention. Based on

these ergonomic investigations, interventions that may be behavioral, organizational, or design-related should be proposed as mitigating strategies to prevailing ergonomic stressors to improve the OSH and productivity scenario of these FMCG shop-floors.

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Ergonomics Analysis of Working Posture in Household Cleaning Using Technomatix Modeling

Rajat Pratap Singh, Parveen Kalra, and Suman Kant

Abstract Household and commercial cleaning is a vital virtue of life. It is advantageous in many ways, and the prime one being it helps to keep an individual healthy. Cleaners working in this area are faced with serious musculoskeletal disorders (MSD), due to prolonged hours in the same posture, repetition in the task, contact stress due to tools or postures. The objective of this study was to explore upper limb musculoskeletal disorders and postural risk among cleaners. In this study, awkward working posture takes on by cleaners in houses has been observed and analyses using ovako working posture analysis system. A housework system model is developed and simulated in computer-aided ergonomics assessment tool Technomatix with implicit cleaners with their specific systematic measurement of the physical properties of the human body. Trunk postural load was found more significantly and also motion angle of the wrist was found repetitive.

Keywords Musculoskeletal disorder · Technomatix · Ovako working posture analysis · Ergonomics · Cleaners

1 Introduction

The main aim of cleaning is to remove undesired dust, marks, and unwanted material from useful locations. Cleaning work should be carried out without unveiling cleaners to the possibility of injuries or physical risk [1]. While compatible estimates on domestic workers in India are hard to obtain, with a formal and informal estimate on a straightforward number of domiciliary workers in India, considering the data of (NSSO) is more often accurate [2]. ILO (International Labour Organization) reports on domestic workers is quite interesting which is having legal protection across countries, the report of ILO 2010 shows that there were more than 62 million domestic workers and this figure will increase in India till today (ten years).

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1.1 Injuries and Physical Risk in Cleaning

Various studies on cleaning method describe that most higher risk factor is associated with lower back and lower limb [3]. There are lots of hard-working body postures during mopping, wiping, surface cleaning, polishing, etc. The cleaners faced so many problems/pain during all these activities like lower back pain, neck pain, upper limb, and lower limb disorder. While cleaning they have to do one step in a quite repetitive manner, which leads to wrist joint pain [4].

Lower back pain is defined as the accurate pain which occurs in a lumbar area called lumbago, and an upper area called Sciatica [5]. Neck and upper limb are defined as the disorder or pain in muscles, joints, or in the localized shoulder area. These above-mentioned injuries and pain occurred due to awkward postures, repetitive movement or insufficient rest period, and also working in unorganized space [6]. Cleaners adopt different awkward postures while performing their jobs. Sometimes some postures are very harmful, even they continue doing their work for a long time, various work postures which are performed by workers are physiological demanding and time-consuming. Although the women cleaner performing the job in forwarding bending and squatting postures, these postures can cause serious physical risk and injuries.

The injury rate in the cleaning occupation is higher compared to other occupations in cleaning [7]. The injury frequency rate (all injuries) is 23.1 injuries while other occupation 10.5 injuries. The injury incident rate (all injuries) is 25.6 injuries while in other is 17.7 injuries.

The aim of the study was:

1. To analyze work posture in cleaning posture.
2. To develop a virtual human stimulation in Technomatix software for the OWAS method.
3. To improve the work postures identified as poor.

2 Methodology

Posture analysis is used to identifying the awkward postures while performing works and movement measurement is an important factor in the determination of the physical examination process on performing work activities. There is a high risk for injuries are associated with these awkward postures [8]. The below two studies have been carried out for assessing the work condition in cleaning occupation.

2.1 Subjects

In this study, a total of 18 cleaners participated from Punjab engineering college, Chandigarh, out of which 11 are female (aged range: 32–49 years), and 7 are male

Table 1 Subject characteristic of cleaners

Subject characteristic	Mean	Standard deviation	Maximum	Minimum
Age (years)	38.21	5.87	49	29
Height (cm)	165.21	3.53	180	152
Working years (years)	11.01	5.09	21	3
Weights (kg)	62.60	5.5	80	49

(aged range: 29–47), and also 4 cleaners were refused to participate in the study. The average working years of total participation was 11 years (range: 3–21 years). Participated cleaners were working in various departments of the colleges.

2.1.1 Sociodemographic Characteristics

A total of 18 cleaners participated in this study with a response rate of 99.5%. Out of the 18, 11 (61.11%) were female and 7 (38.89%) were male. The age range was between 29 and 49 years with a mean age of 38.21 and a standard deviation of 5.87. The Height range of cleaners was 152–180 cm with a mean height of 165.21 and a standard deviation of 3.53. The weight range was between 49 and 80 kg with a mean weight of 62.60 and a standard deviation of 5.5. The mean working years of cleaners were 11 years (Table 1).

2.2 Biomechanical Study

The main objective of this study is to study the structure, function, and motion of the body, and according to that, we finalize a standard size of the population. The goal of the biomechanical model is to know about the continuous pain and movement of body parts or the work which is done with excessive effort [9].

In this study, the computer aid Ergonomics tool "Technomatix Process Human Stimulate" version 16 was used to analyze the lower back compression forces and awkward posture. Anthropometric data i.e. body, weight, age was used for creating virtual human representation in the software. These data were taken from the cleaners who were working in colleges. Anthropometric Asian databases were used but height, weight, age, and other demographic properties of cleaners used were asked while performing the study. Technomatix Human Process Simulate from Siemens is software that can be used for ergonomics analysis of Human i.e. OWAS Score, Fatigue, Low back compression, Rapid Upper Body Assessment, Strain index, etc. (Fig. 1).

The low back compression analysis tool is part of jack's task analysis tool kit. It helps to calculate the spinal force acting on a virtual human's lower back under any posture and loading condition based on complex biomechanical low back model consolidate the updated automatical and physiological data of virtual human which

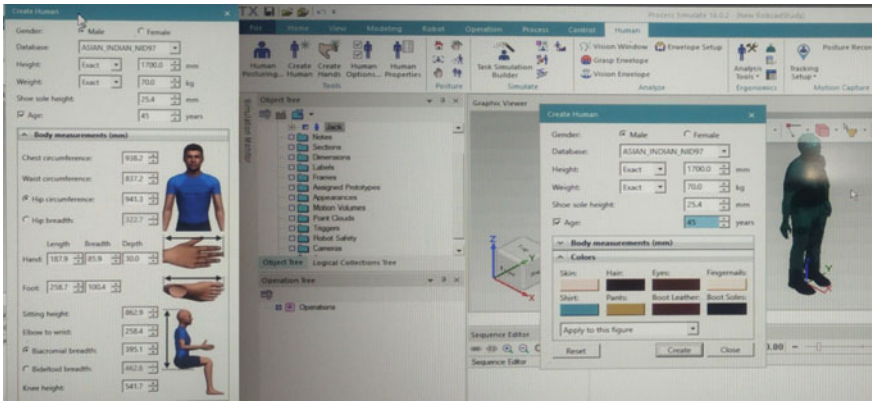


Fig. 1 Virtual jack creation with ASIAN_INDIAN anthropometric data

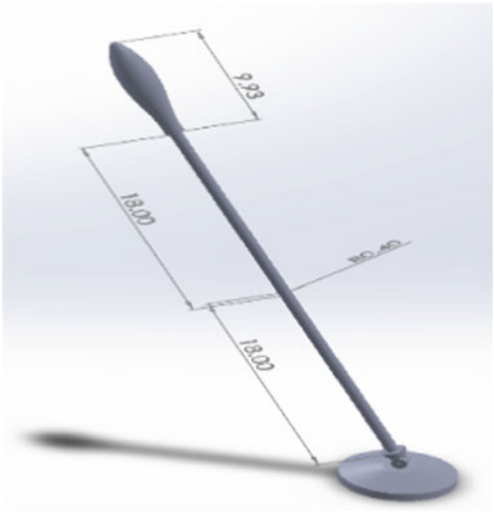


Fig. 2 Mop structure used by cleaners (all dimension are in inches)

created in Human simulate as shown in Figs. 3 and 4 [10]. Use the technomatix process stimulate in a study and evaluate the performance of the jack and potentiality of software and its function. In this study cleaning activities using the moping tool were used for analysis. Body posture angle measure during cleaning activities using the mop and these measured angles were used for attaining posture in Technomatix software and OWAS, low back compression analysis was used for assessment of cleaners. This process was repeated for all subjects at various times. The structure and dimension of the mop which was used are shown in Fig. 2.

Several manual tasks involve important body movement, it continues to be very helpful to evaluate specific exertion within a cleaning task and performing static biomechanical analysis. Such analysis is normally evaluated by joining the postural

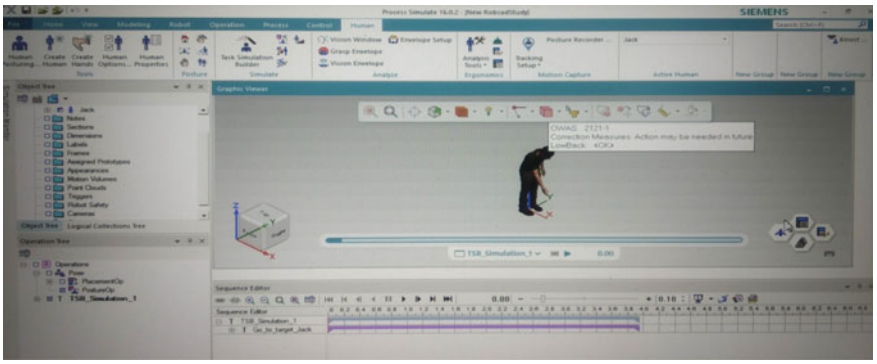
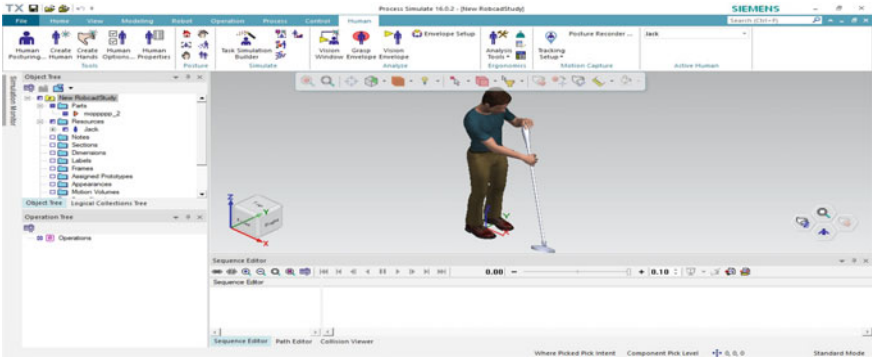
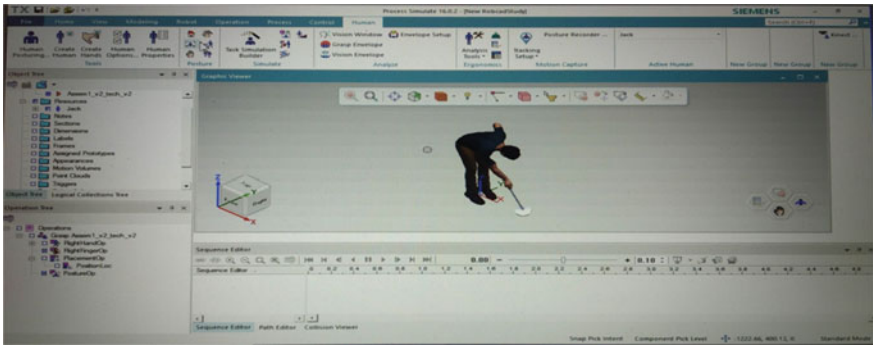


Fig. 3 Posture loading condition



(a)



(b)

Fig. 4 **a** Lower back analysis (Lumbago) and OWAS assessment of cleaner (Position 1). **b** Lower back analysis (Lumbago) and OWAS assessment of cleaner (Position 2)

information (body analysis) which are contained from stopped videos, images, or still photos of a cleaner [11]. The biomechanical model used for personage strength and spinal segment force prediction is mathematically very intensive, especially in 3Dimensional form. The benefit of using 3Dimentional human modeling using computer software that operates has whole control on dimensional or percentile values of each aspect of human models and can interactively change them in a matter of seconds [12].

2.3 Postural Analysis

Postural analysis is a frequent technique that has been used on a big platform by researchers since body posture is one of the major factors that influence muscular strength [13]. The most common aware method is the ovako working posture analysis (OWAS).

OWAS is a method for examining and dominating awkward working postures. The fundamental of OWAS is to provide a system for analyzing and categorizing working postures. The changeability of its posture coding constituent provides applicability to most working postures. As explained in its original forms that are 252 postures combinations, all of which are allocated by action codes [14]. OWAS has shown joining validity when compounding to other posture recording techniques such as Rapid Entire Body Assessment (REBA) [15]. The inter-observer reliability of OWAS is excellent with measuring medium reliability of 93% [16].

The use of computerized OWAS application makes the analysis fast and versatile than the traditional pen and paper method. While performing cleaning activities there is a repetitive motion of hand and also of the wrist as shown in below images. This frequent repetitive motion of wrist leads to MSD and also awkward posture The use of a computerized application is strongly approved [17]. Some postures which were attained by cleaners are shown in Fig. 5.

2.4 Coding of OWAS Working Position

Here is the order of the five digit in the OWAS code. BACK ARMS LEGS LOAD—HEAD.

In process stimulate humans, value for the body part of the code are shown as Fig. 6.

Four action categories which are required while analysis owas are as follow:

1. AC1 (no action is required)
2. AC2 (Corrective measures are not needed immediately)
3. AC3 (The corrective measures must be affected as soon as possible)
4. AC4 (The corrective must be effected immediately).

Fig. 5 Cleaner doing mopping on the floor

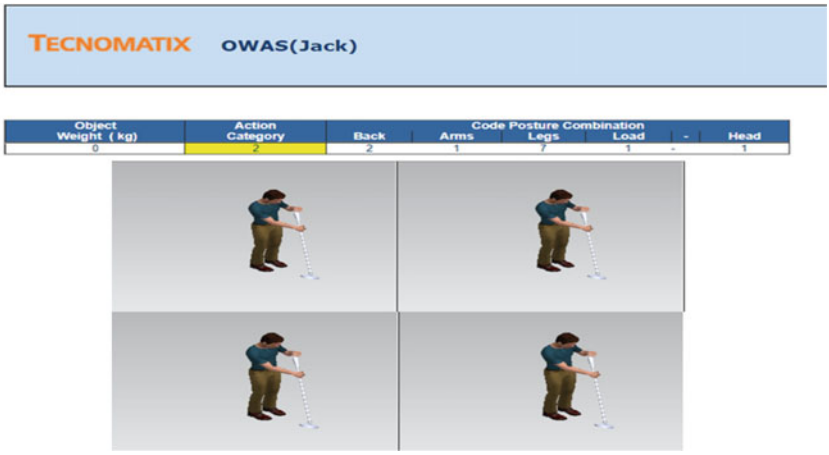
Fig. 6 Value for each body part in technomatix process simulate

3 Result and Discussion

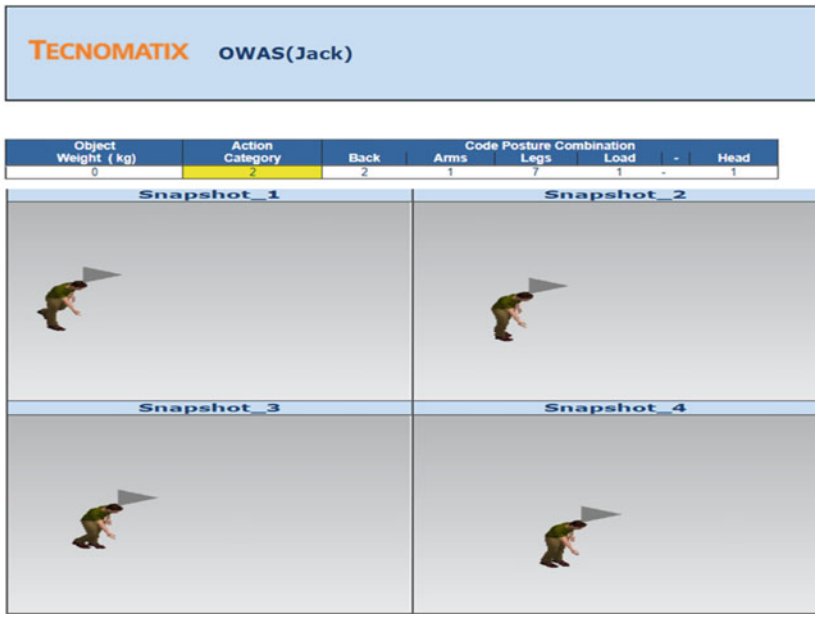
Owas posture analysis report shows that, left hip flexion and left ankle extension was more enough which is the main reason for pain and injury, although wrist flex was of higher degree as shown in Tables 3 and 4 during mopping the surface. Technomatix owas report showing that owas action category 2 required for correctness for the posture as shown in Fig. 7.

From the report, owas posture code appear as (Table 2)

Figure 7 conclude various factor which contributes to injury in cleaning occupation i.e. repetitive work and awkward working posture. After analyzing this cleaning method it was seen that the level of exertion is more during mopping the surface. The lesson for the problem is that consideration of more equipment will be more suitable



(a)



(b)

Fig. 7 **a** Owas category and posture code of the simulation while mopping the surface (Posture 1). **b** Owas category and posture code of the simulation while mopping the surface (Posture 2)

Table 2 Owas category and posture code

2	1	7	1	1

Table 3 Wrist, shoulder, and trunk capability chart during simulation

Capability summary chart											
		Left					Right				
		Moment (N m)	Muscle effect	Mean (N m)	SD (N m)	Cap (%)	Moment (N m)	Muscle effect	Mean (N m)	SD (N m)	Cap (%)
Wrist	Flex/Ext	1.2	EXTEN	67.5	19.7	100	0	–	0	0	100
	Rad/Ulnar dev	0	–	0	0	100	0	–	0	0	100
	Sup/Pro	0	–	0	0	100	0	–	0	0	100
Elbow		− 67	–	296	94	100	− 1.4	FLEX	60.3	14.8	100
Shoulder	Abduc/Adduc	− 3.8	ABDUCT	80.1	19.7	100	− 4.7	ABDUCT	86.4	21.3	100
	Rotation Bk/Fd	1.2	BACKWARD	69.5	20.3	100	0	–	0	0	100
	Humeral rot	0	–	0	0	100	0	–	0	0	100
Trunk	Flex/Ext	− 55.1	EXTEN	291.6	91.9	99.5					
	Lateral bending	0	–	0	0	100					
	Rotation	0	–	0	0	100					
Hip		− 30.1	EXTEN	198.4	79.6	98.3	− 29.8	EXTEN	198.4	79.6	98.3
Knee		− 24.6	FLEXN	140.8	41.5	99.7	− 24.1	FLEXN	140.8	41.5	99.8
Ankle		− 40.3	EXTEN	149.2	49.3	98.6	− 39.9	EXTEN	149.2	49.3	98.7

Table 4 Wrist, shoulder, knee, ankle, and trunk joint chart during simulation

Joint angle summary (deg)				
Calculated limb angles			Calculated trunk angles	
	Left	Right		
Wrist Flex/Ext	121	97	Trunk flexion	63
Wrist Rad/Ulnar	34	78	Trunk lateral bend	65
Forearm	98	65	Trunk rotation	0
Elbow included	126	176		
Shoulder vertical	15	62		
Shoulder horizontal	− 50	85		
Humeral rotation	− 39	− 10		
Hip included	146	146		
Knee included	170	170		
Ankle included	83	83		

for the cleaners and equipment should be trailed before purchase to make suitable for a work environment. While moping various hazards are identified when stopping to mop under furniture, Cleaners were squatting forward over 65°, and also, cleaner had to stretch to access some areas which adopt awkward shoulder posture.

The cleaner hand was twisted when mopping using a mop for the selection of this problem. Some suggestion and lesson are as follow:

1. Matching equipment to cleaners will reduce pain and injuries problem. This must apply to the shorter stature cleaners.
2. It is must cleaner know how to use the equipment correctly and it is full capacity, day to day proper training should be given to cleaners.
3. Another solution is that the mop should provide with some extended handle.

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Study of the Effect of Worker Characteristics on Maximum Acceptable Weight of Lift

Saman Ahmad and Mohammad Muzammil

Abstract Manual material handling (MMH) and lifting activities have been identified as risk factors for low back pain (LBP). Statistical findings suggest that about 50% of all back pains are related to manual lifting. Of the many tools available for analyzing and designing lifting tasks, the revised NIOSH lifting equation (RNLE) is perhaps the most widely used. An inherent limitation of the equation is that it addresses task demands only. However, load lifting task is dependent not just on the characteristics of lift but on worker characteristics like age, gender, weight, anthropometry and ethnicity. Thus, the present study investigates the role of worker characteristics like age, gender, BMI and anthropometric variables in a manual lifting task. A psychophysical methodology was adopted to arrive at the maximum acceptable weight limits (MAWLs). 44 industrial workers (22 males and 22 females) participated in the study. ANCOVA for gender using age, height, acromial height and BMI as covariates showed that BMI, gender and age had statistically significant effect on MAWL while the effect of height and acromial height was statistically non-significant. Further, it was observed that the recommended weight limit (RWL) as obtained by the RNLE was 17.2 kg. However, using the psychophysical criteria of 75th percentile women (as per the RNLE guideline), in the present study a MAWL of 19.3 kg was found.

Keywords Manual material handling · Manual lifting · Revised NIOSH lifting equation

1 Introduction

Manual material handling (MMH) and lifting activities have been identified as risk factors for low back pain (LBP) [12], which in turn results in significant human suffering, loss of productivity, and an economic burden on compensation systems.

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LBP is believed to be the greatest contributor to global disability in terms of years lived with disability [3].

While a number of tools, like the revised NIOSH lifting equation (RNLE) and Snook tables, are available for the analysis of manual lifting tasks, most of them consider the effect of task variables only. The RNLE is perhaps the most widely used tools to identify increased risk of back pain [4]. It comprises of a load constant and six task-related multipliers and is as follows:

$$\mathrm{RWL} = \mathrm{LC} * \mathrm{HM} * \mathrm{VM} * \mathrm{DM} * \mathrm{AM} * \mathrm{FM} * \mathrm{CM}$$

where

LC = Load constant
HM = Horizontal multiplier
VM = Vertical multiplier
DM = Distance multiplier
FM = Frequency multiplier
CM = Coupling multiplier.

The multipliers may take up values ranging from 0 to 1. RNLE assumes that under ideal lift conditions, i.e., when all the multipliers have a value of 1, a load of 23 kg (load constant) may be lifted without an increased risk of back injury to the average worker. Together, the load constant and multipliers yield a recommended weight limit (RWL). It is believed that almost all healthy workers may lift loads equal to or less than the recommended weight limit (RWL) safely [5].

However, the performance in a load lifting task is dependent not just on the characteristics of lift but also on worker characteristics like age, gender, weight, anthropometry and ethnicity. Psychophysical rating of lift has been found to have a relationship with strength and gender of the lifter [6]. An association between seeking care for low back pain (LBP) and demographic factors like age, gender and BMI has also been observed[7].

Gender and age have a significant effect on lifting capacity [8]. Maximum acceptable weight limit (MAWL) of females is about 53% of their male counterparts [9]. Their chances of experiencing high physical exertion are 8–9 times higher than men [10]. Muscle activation pattern during isometric lifting tasks has also been found to be gender-specific [11]. Females apply more hip flexion while males flex their lumbar spine during lifting tasks [12]. Differences in inter-joint coordination between women and men performing a lifting task have been documented [13, 14]. However, no difference in lifting techniques between men and women is observed when load is adjusted to the subject's strength [14–17].

Anthropometry has been implicated for variations in MAWL. For MMH tasks involving lifting, lowering and carrying, spinal moments increase with increase in subject's height and weight [18]. Anthropometric characteristics of chest circumference, acromial height and wrist circumference account for 56.2–83.4% variance of MAWL [19]. According to Lee and Chen (1996), 86–91% of the variance in

MAWL is the result of modified composite strength (MCS), chest circumference, and acromial height [20]. Muslim et al. (2013) highlighted the need for adjustments in the RNLE to account for the differences in anthropometry of Indonesians and the Americans [21]. Maiti and Ray (2004) developed an equation for maximum load limit of Indian women using physiological measures. On the basis of this equation, they recommended a maximum load limit of 15 kg for manual lifting by adult Indian women [4].

It is believed that both physical strength and physiological functions decline with age [22, 23]. For the same lifting task, oxygen uptake and heart rate increase with increase in age [24]. Older female workers have a significantly lower MAWL and grip strength as compared to their younger counterparts [25]. MAW has been found to increase with age, peak in the age group of 29–38 years followed by a gradual linear decline [26]. Contradictory findings have also been reported. It has been suggested that older individuals tend to use better strategies as compared to younger adults and any increase in LBP risk in older workers is the result of age-related physiological changes [27, 28]. There is no association between age and physical exertion of blue-collar workers according to Andersen et al. (2018). They however attributed this to the presence of a 'healthy worker effect' [10]. According to Lin, Wang and Chen (2006) there is no significant age-related difference between physically active older population (55–74) and younger groups (18–35 years) [29].

With the increasing problem of obesity, efforts have been made to study the relationship between body mass index (BMI) and lifting tasks. While a significant relationship between fat-free mass and maximum lifting capacity has been documented [30], there is a lack of consensus on the actual nature of the relationship. An increase in MAWL with increase in BMI has been reported [31, 32]. On the other hand, lower acceptable loads for subjects with more body fat have been seen [33]. MAWLs for obese and non-obese workers is comparable according to Sangachin and Cavuotoother (2016) [34]. Though, Andersen et al. (2018) also found no relationship between BMI and physical exertion a majority of their workers were either normal weight or only slightly overweight [10].

2 Methodology

Experimental investigations were carried out to establish the effect of acromial height, gender age and BMI on maximum acceptable weight limit. A psychophysical method was adopted. 44 subjects, 22 men and 22 women, participated in the study. The subjects were industrial workers, mainly involved in manual labor. All subjects were healthy and had no history of back pain, requiring medication, in the past 6 months. Trial runs were conducted to familiarize the subjects with the procedure.

2.1 Experimental Procedure

Before starting the experiment, the subjects' heights, and weight were recorded. The values of the anthropometric data are given in Table 1.

They were informed about the procedure and possible risks involved and their consent was obtained. Subjects were allowed to rest for at-least 20 min prior to starting the experiment.

A psychophysical method was adopted to arrive at the MAWL. The start and finish position of the lift were measured between the ground and the middle of the handle. Handle type and lifting heights were chosen so as to maintain the distance multiplier, vertical multiplier, asymmetry multiplier and coupling multiplier of the RNLE at 1. Thus, the experimental task involved lifting a box of unknown weight from a height of 75 cm and placing it at a platform 100 cm from the ground at a frequency of 0.5 lifts/min. The size of the box used was 40 cm * 34 cm * 20 cm. Comfortable handles were provided for easy lifting at a height of 20 cm from its base. In order to avoid visual cues, the box contained a false bottom that could hold up to 8 kg of weight. Subjects were aware of the false bottom but they did not know how much weight it contained for any given lift. The experimental set-up is shown in Fig. 1.

Table 1 Anthropometric data of subjects who participated in the study

		Height (cm)	Weight (kg)	Age (years)
Women	Average	1.469	43.595	37.32
	Std. Dev	0.062	6.923	9.978
Men	Average	1.610	59.393	40.95
	Std. Dev	0.068	9.6153	9.599

Fig. 1 Subject performing the experimental task

Subjects were instructed to adjust the weight of the box to one that they could potentially lift for an entire workday, without getting exhausted or out of breath. To indicate the start of a lift a buzzer was used. After every lift, the subjects were encouraged to increase/decrease the load, by adding or taking out metal strips, so as to arrive at a load they felt comfortable with.

Every experiment was of 40 min duration, divided into two segments of 20 min each. At the beginning of each segment the subject started with an unknown weight (either very high or very low). They adjusted the load, to one that they felt they could lift for an entire workday. Thus, two weights were obtained in the two sessions. If they were within 15% of each other, their average was noted down as the MAWL. If the difference between them was higher, the set was discarded and the entire experimental run was repeated.

3 Results and Discussion

Observations gathered using the above methodology were analyzed using ANCOVA for gender using age, height, acromial height and BMI as covariates. Results obtained are shown in Table 2

As evident from the table, BMI, gender and age had a significant effect on MAWL. Height and acromial height were found to have no statistically significant effect on MAWL, for the task undertaken in the present study.

The effect of gender on MAWL was statistically significant. It was observed that while the average weight lifted by females was 18.2 kg (standard deviation 2.82), males lifted an average of 26.2 kg (Standard deviation 4.73). The results are in line with many previous researchers. Jackson and Sekula (1999) observed that

Table 2 ANCOVA results for the effect of gender with age, height, acromial height and BMI as covariates, on MAWL

Tests of between-subject effects					
Source	Type III sum of squares	df	Mean square	F	Sig
Corrected model	896.416a	5	179.283	15.513	0.000
Intercept	2.287	1	2.287	0.198	0.659
Age	100.950	1	100.950	8.735	0.005
Height	2.316	1	2.316	0.200	0.657
BMI	88.072	1	88.072	7.621	0.009
Acromial height	0.171	1	0.171	0.015	0.904
Gender	155.491	1	155.491	13.455	0.001
Error	439.152	38	11.557		
Total	22,951.763	44			
Corrected total	1335.568	43			

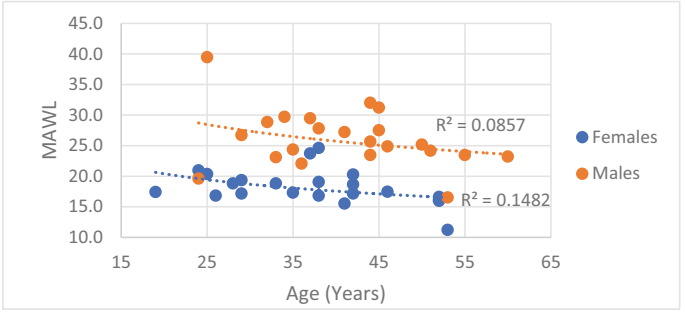

Fig. 2 Effect of age on MAWL of a subject performing a lifting task

psychophysical lift capacity was a function of gender [6]. Matheson et al. (2014) in their evaluation of the EPIC Lift Capacity test found significant gender differences [8]. It has been reported that males have a higher MWL and MAWL as compared to females [26, 32]. The MAWL of females in the present study was 69% that of their male counterparts. This is in line with the results of Plamonden et al. (2014) who reported that lifting strength of women ranges between 45 and 76% of men [14].

For the task under consideration, a statistically significant effect of age on MAWL was observed. As evident from the graph, the MAWL decreased with increase in age for both males and females (Fig. 2). Further, for both men and women, the decrease in MAWL follows the same pattern. The decrease in physical capacity with increase in age is well established. Age was found to have a significant effect on MAW of male workers [26]. Chen et al. (2017) found significantly lower MAWL in older female workers as compared to their younger counterparts [25].

There seems to be a lack of consensus among researchers regarding the effect of workers weight on lifting capacity. Jackson (1997) observed that fat-free mass was significantly related to maximum lifting capacity [30]. While some investigators have reported an increase in MAWL with increase in BMI [31, 32], others found no relationship of BMI with physical exertion and MAWL [10, 34]. Lower acceptable loads for subjects with more body fat have also been reported [33]. Also, obesity has been linked to higher L5/S1 disc compression, for similar tasks [35]. The significant increase in peak lumbar loading during lifting/lowering tasks, in obese workers, has been attributed to their anthropometric characteristics [36]. Thus, most research seems to suggest that higher BMI has a detrimental effect on the lifting task. In the present study a statistically significant effect of BMI on MAWL was observed. It was seen that MAWL decreased with increase in BMI for both male and female subjects (Fig. 3). Further, since the back compressive forces were not studied in the present study, the impact of BMI on lifting tasks may be more severe. Thus, BMI needs to be taken into account while deciding safe load limits, keeping in mind the rise in obesity worldwide.

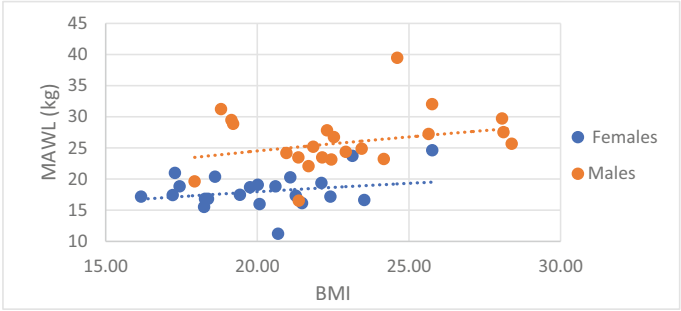

Fig. 3 Effect of body mass index on MAWL of a subject performing a lifting task

No effect of height or acromial height on MAWL was seen for the present experimental task. It is possible that since the task was carried out at a single comfortable height of lift, it did not show any significant effect. More anthropometric characteristics need to be investigated to be able to establish a relationship between anthropometry and lifting capability.

The revised NIOSH lifting equation (RNLE) the physiological (maximum energy expenditure of 2.2–4.7 kcal/min), psychophysical (weight acceptable to 75% of female workers), and biomechanical (maximum L5-S1 compressive force of 3.4 kN) [37] criteria for arriving at the recommended weight limits (RWLs). Load limits based on all three criteria were established and the lowest amongst them was used to determine the RWL. It is generally believed that the psychophysical method encompasses both biomechanical and physiological methods for low frequency tasks (frequency less than or equal to 4 lifts/min) [38] and is therefore a valid estimate for RWL at these frequencies.

For the task undertaken in the present study, the RWL, calculated using RNLE, was found to be 17.2 kgs. This is considerably less than the MAWL (19.3 kg) obtained in the present study using the psychophysical criteria of the RNLE, namely, the 75th percentile female. The RWL of the RNLE ensure that manual lifting job does not exceed the acceptable lifting capacity of about 99% of males and 75% of females—or 90% of the working population (assuming a working population that is 50% male and female). However, in the present study, the MAWLs were found to be 19.3 kg, 37.9 kg, 29.3 kg respectively. The reason for the apparent contradiction may be that the RWL of the RNLE were developed using mainly American subjects and do not take into account the well documented effects of ethnicity on lifting capabilities and MAWL [20, 39–43]. Also, a number of studies have highlighted the conservative nature of the RNLE [30, 44, 45]. It is believed to underestimate the lift capacity of many individuals [33]. Further investigations are required to establish the reasons for the observed difference.

4 Conclusions

The results of the present study indicate that while anthropometric characteristics of height and acromial height had no significant effect on MAWL, age, gender and BMI of a worker significantly affected it. It was noted that for the task undertaken in the study the MAWL, as per the RNLE criteria, is 19.3 kg which is much higher than the RWL of 17.2 kg as obtained from the RNLE. This points towards the need to consider the worker characteristics while deciding the acceptable weights of lift. The characteristics may also be used for worker selection for situations where high loads are to be handled. Further, separate load limits may be defined for males and females. This would allow the optimal use of manpower without any increased risk to the female workers.

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Postural Assessment of Indian Floor Tilers' Using OWAS, REBA, ERIN and WERA Methods

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Abstract Work-related musculoskeletal disorder (WRMSD) is a common health problem amongst construction workers due to working in awkward postures and other related ergonomic risks. Flooring or tilling is one of the major works incorporated in construction where tilers' work in squatting, stooping and kneeling posture for prolong time. The main objective of the current investigation is to study different task carried out during the tilling process, identify the most vulnerable task posture and find the level of ergonomic risk amongst the tilers in India using different ergonomic tools. A total of 30 tilers were observed, interviewed and video recorded for analysis. The tilling work was classified into six tasks and most exposed postures were identified for analysis. OWAS, REBA, ERIN and WERA methods were used to find the level of risk. The tilers have severe pain or discomfort in the lower back (76.67%), knees (76.67%), legs (calf) (60%), arms/hand (43.33%) and ankle/toe (20%). The results of the OWAS, REBA, ERIN and WERA also revealed that the claims of the tilers are true and tilers are working at high to very high ergonomic risk. The finding of the study leads to the conclusion that tilers in India have undoubtedly high rates of work-related musculoskeletal disorders (WRMSD) and are highly affected due to prolong working in squatting, stooping and kneeling posture.

Keywords Tilers' · WRMSD · OWAS · REBA · ERIN · WERA

1 Introduction

Construction work is physically demanding work and work-related musculoskeletal disorders (WRMSD) are a frequent health problem faced by construction workers. The construction work is dynamic and the assessment of such dynamic work is complicated. As noted down by many researchers, construction workers are suffering

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from low back disorders due to working in awkward postures, working in bending or twisting position, repetition of work [1–3].

In the construction of a house, flooring or tiling is one of the important parts. In the early seventies, in India, either a plain or concrete floor was applied for flooring. In today's modern scenario flooring or tiling is not just consider a floor but it is more than that which increases the overall look of the house. Nowadays many different types of flooring are used viz. concrete flooring with sand and cement mortar thereafter flooring with red oxide flooring to marble floor fitting, PVC flooring, granite floor fitting, mosaic tiles floor fitting, vitrified tiles fitting. Nowadays, the most popular flooring tiles used in India is vitrified tiles. These tiles are available in different size and designs and give aesthetic look to the house floor.

The process of flooring or fitting tiles is hazardous and dangerous work in which tilers' need to work at ground level and requires to work in non-neutral body posture throughout the day. Nearly one-third of the working times, tilers' work in squatting, stooping and kneeling posture. This increases the health problems and WRMSD problems among the tilers'. The most hazardous and exposed body part in this is the lower back, legs (calf) and knees. To avoid physical health issue due to ergonomic risk a thorough evaluation of risk is needed.

Therefore, this paper aims to evaluate the working postures of tilers' to discover the work-related musculoskeletal disorders (WRMSD) causes while doing the different task of tiling work. Before evaluation, the six tasks have been identified and the most vulnerable posture of these tasks have been selected for evaluation.

2 Methodology

A three-week study has been carried out at different construction sites where tilling work was going on. A total of 30 tilers were observed, interviewed and video recorded for analysis. Table 1 represents the background characteristics of all tilers. An anthropometric scale and standard weighing machine were used to measure the height and weight of the tilers'. Personal data like age, daily working hours, procedures and pain/discomfort other related problems were discussed and noted. The tilers were between 31 and 58 years of age, with working experience of 8–35 years. The tilers have to perform six tasks for tile fitting. Table 2 shows Task details, real image and

Table 1 Demographic characteristics of tilers

Characters	Mean ± SD
Age (years)	46.27 ± 6.64
Weight (kg)	61.32 ± 5.27
Height (cm)	161.67 ± 5.28
Experience (years)	21.30 ± 6.91
BMI (Kg/m^2)	23.50 ± 2.04

Table 2 Different task carried out by tilers' and body position while working

Task	Real images of task	Task description	Body position
T1 (Floor surface leveling)		The floor surface is leveled using concrete or sand and cement lean mortar. 1 to 2 in. thick concrete or sand and cement lean mortar spread over the rough floor	(1) Sit in squat position on toes (2) Legs flexion at knee (bent): >900 (3) Ankle extension (4) Both arms below shoulder level (5) Trunk flexion /lateral right position (6) Forearm pronation
T2 (Tiles level pads marking)		The level pads are marked at corners of the floor for uniform spreading of tiles on floor	(1) Sit on kneeling position (2) Legs flexion at knee (bent): >900 (3) Ankle extension (4) Left arm above shoulder (5) Right arms below shoulder (6) Left shoulder abduction (7) Truck and neck in extension position
T3 (Cement slury pouring as a binder)		Cement slurry spread on the surface which is use as a binder	(1) Sit on kneeling and squatting position (2) Legs flexion at knee (bent): >900 (3) Ankle extension (4) Arms below shoulder (5) Left wrist extension (6) Truck in lateral left position (7) Neck in flexion position (8) Right arm fingers in flexion (9) Left arm fingers in extension

(continued)

Table 2 (continued)

Task	Real images of task	Task description	Body position
T4 (Scratch cement slury for proper binding)		After pouring the slurry, the scratches are marked on the poured slurry for proper binding of tiles with floor surface	(1) Sit on kneeling and squatting (2) Legs flexion at knee (bent): >900 (3) Ankle extension (4) Arms below shoulder (5) Left wrist extension (6) Truck in lateral left position (7) Neck in extension position (8) Right arm fingers in flexion (9) Left arm finger in extension
T5 (Placing of tile on leveled floor on slury)		Tiles are placed on the poured slurry by maintaining tile point with other fitted tile	(1) Sit on squatting position (2) Legs flexion at knee (bent): >900 (3) Arms below shoulder (4) Neck in flexion position (5) Trunk flexion (6) Arms are abduction position
T6 (Tile levelling)		Tiles are leveled by light tamping with wooden mallet for proper leveling using reference lines of level pads for smooth level and slop. The tile joints are then filled with white cement	(1) Sit on squatting position (2) Legs flexion at knee (bent): >900 (3) Arms below shoulder (4) Neck in extension position (5) Trunk flexion (6) Arms are abduction position (7) Right arms fingers flexion position (8) Left arms finger extension position

Table 3 Number and percentage of tilers' complaint about pain

S. No	Body parts	Pain	% of pain
1	Head	0	0
2	Neck	0	0
3	Shoulders	0	0
4	Chest	0	0
5	Arms/hands	13	43.33
6	Wrist	4	13.33
7	Lower back	23	76.67
8	Legs (Calf)	18	60.00
9	Knees	23	76.67
10	Feet, ankle and toe	6	20

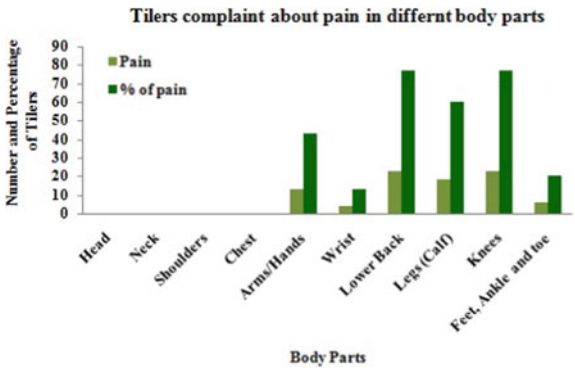

Fig. 1 Graph showing number and percentage of tilers' complaint about pain

body position while doing the task. The number and percentage of tilers complaints about pain or discomfort in different body parts are shown in Table 3 and Fig. 1. Numerous methods are available for the assessment of ergonomic risk. In this paper OWAS, REBA, ERIN and WERA applied for evaluation of the working postures of the tilers.

2.1 Ovako Work Posture Analyzing System (OWAS)

Karhu et al., 1977 developed this is a simple observational method used to analyze and control poor postures. The method is based on a whole-body sampling of working posture that covers working postures of the Back, Upper limbs (Arms) and Lower limbs (Legs) and forces with precision [4].

2.2 Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment (REBA) is the most popular quick observational and survey method used for assessment of static and dynamic movements, rapid changing or unstable body posture. The REBA method was developed using the concept of RULA, OWAS and NIOSH method in which the author's added risk of knee, loads/forces, coupling, repetition and activity of the whole body and further extended for unpredicted working postures of a sensitive task [5].

2.3 Evaluation Del Riesgo Individual/Individual Risk Assessment (ERIN)

Rodriguez et al., 2013 developed Evaluacion del Riesgo Individual/Individual Risk Assessment (ERIN) method with available ergonomic tools, epidemiological data with a purpose to evaluate static and dynamic work by non-experts persons, with less training and without equipment [6]. They focused on factors like workplace and worker assessment. The worksheet of ERIN has been designed using available ergonomic tools like RULA, REBA, SI, QEC, OCRA and OWAS. This method measure posture, frequency of movement of the trunk, shoulder/arm, hand/wrist and neck that results from speed of work, task duration, the intensity of effort and self-assessment [7].

2.4 Workplace Ergonomic Risk Assessment (WERA)

Md. Nasrull Abdol Rahman et al. develop this pen and paper method (WERA) to assess the WRMSD amongst the wall plastering, bricklaying and floor concreting workers of the construction work. The method is a quick observational method that gives a screening method to working task for exposure physical risk factor related to WRMSD. The method comprises posture, repetition, force, vibration, contact stress and task duration including five body parts which are neck, shoulder, wrist, back and leg. The method can use in any space of workplaces without disturbing the workforce [8].

3 Results and Discussion

In this study, an ergonomic risk score for five tasks postures has been evaluated using OWAS, REBA, ERIN and WERA methods for six postures of six different tasks carried out during tilling work (Table 2). From the study, it is found that the

tilers complain about pain in the lower back (76.67%), knees (76.67%), Legs (calf) (60%), arms/hands (43.33%), feet/ankle/toe (20%) and wrist (13.33%). (Table 2 and Fig. 1) From the complaints raised by the tilers', it is found that the body parts affected more is the lower back, knees, legs (calf) and arms/hands.

From the postures of all tasks, it is revealed that in all tasks tilers are working in stooping, squatting and kneeling postures on foot toes for one-third of the total working time. Tilers' have to get up every 4–6 min to pick tiles or tools or materials.

In all the tasks, the right-hand side of the tilers' is appeared to be more engaged in working while the left hand of the tilers' are idle or used for support. Even the left arm is not the right position when supporting to the body. To get support, tilers' placed all body weight on the wrist and fingers to bend 90°. The neck is in the extension position in task 2, 3 and 4.

For tamping the tile for levelling, tilers' use a wooden handle of the hammer instead of a wooden mallet. It is observed that while tamping, tilers' hold the iron head of the hammer. While tamping, the hand and fingers feel vibration and contact stress effect because of poor grasping and hard iron head. The tilers' never use any hand gloves while working hence stress due to contact and vibration directly affect the fingers, wrist and hand.

The result of all methods used, revealed that tilers' are at ergonomic risk while doing all the tasks from medium to high and very high risk. The detailed result is shown in Table 4a–d. From the result of the OWAS, task 1 required immediate action for working posture as the final score obtained four. In this task, back (score-4) and legs (score-4) are at high risk. In task 2–4, corrective measures require as soon as possible. In these task legs and lower back are at high risk with a score of 5. OWAS also shows that in task 5 and task 6, the body parts are not highly affected but the possibility is more; hence corrective measure must have to be taken. In these task legs and lower back are at medium risk but the possibility of risk is more if not taken care of.

From the scores obtained from the REBA score sheet for all task, it is found that all tasks are under very high risk except task 6 (for both hands) and task 2 (for right hand). In all tasks, legs and trunk have a high score and are at high risk. REBA score shows that the neck, trunk and legs are at higher risk than the arms and wrist. The body parts which are mostly at risk are the lower back, legs (calf), knees and toes. The score of the ERIN method shows that all the tilers performing all tasks are at high risk but task 6 is a very high risk.

The score obtained from the WERA shows that the tilers' while working task 1 and task 5 are at medium risk and tilers working task 2, 3, 4 and 6 are at high risk. In task 1 and 5 further investigations are required while for task 2, 3, 4 and 6 immediate changes are required. For task 2, the left-hand side of the tilers' body is at high risk while in tasks 3, 4 and 6 right-hand side part the tilers' body is at high risk. However, every task required some changes in working postures.

This study examines the working procedure at the actual construction site by observing, video recording and interviewing the tilers' to recognize the risk factors associated with tilling work. Study shows that tilers' are suffering from work-related musculoskeletal disorders. According to the study, which shows that the most impact

Table 4 **a** Ergonomics risk scores of OWAS

BP	T1	T2	T3	T4	T5	T6
BK/T	4	2	2	2	2	2
UA	1	2	1	1	1	1
L	4	5	5	5	3	3
LD/F	1	1	1	1	1	1
FS	**4&**	**3$**	**3$**	**3 $**	**2***	**2***

b Ergonomics risk scores of REBA

BP	T1	T2	T3	T4	T5	T6
Part A: Neck, trunk and leg						
N	3	2	3	3	2	2
BK/T	4	3	4	4	4	3
L	2	2	2	2	2	2
PS-A	7	5	7	7	5	5
LD/F	1	1	1	1	1	1
TS-A	8$	6*	8$	8$	8$	6*

Part B: Arms and wrist

	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS
UA	3	3	5	4	4	5	4	4	4	4	3	4
LA	2	2	2	2	2	1	2	1	2	2	2	2
W	3	3	2	2	2	2	2	3	2	2	2	3
PS-B	5	5	8	6	6	7	6	5	6	6	5	7
CS	1	1	1	1	1	1	1	1	1	1	1	1
TS-B	6*	6*	9$	7*	7*	8$	7*	6*	7*	7*	6*	8$
TS-C	10	10	10	9	10	10	10	10	10	10	8	9
AS	1	1	1	1	1	1	1	1	1	1	1	1
FS	**11&**	**11&**	**11&**	**10$**	**11&**	**11&**	**11&**	**11&**	**11&**	**11&**	**9$**	**10$**

c Ergonomics risk scores of ERIN

BP	T1		T2		T3		T4		T5		T6	
	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS
BK/T	6	6	4	4	6	6	6	6	6	6	5	5
S/UA/LA	5	5	6	5	5	6	5	6	6	6	5	8
H/W	5	5	5	5	5	5	5	6	5	5	6	6
N	7	7	6	6	6	6	6	6	2	2	3	3
R	3	3	3	3	3	3	3	3	3	3	6	6
IOE	2	2	7	7	6	6	2	2	3	3	3	3
SA	2	2	2	2	2	2	2	2	2	2	2	2

(continued)

Table 4 (continued)

BP	T1		T2		T3		T4		T5		T6	
GR	30$	30$	33$	32$	33$	34$	29$	31$	27$	27$	30$	33$
d Ergonomics risk scores of WERA												
BP	T1		T2		T3		T4		T5		T6	
Part A												
	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS
S	4	4	4	3	3	6	3	6	4	4	4	5
W	5	5	5	5	4	5	4	6	5	5	4	6
BK/T	6	6	6	6	6	6	6	6	5	5	6	6
N	4	4	5	5	5	5	5	5	5	5	6	6
L	6	6	6	6	6	6	6	6	6	6	6	6
Part B												
LD/F	4	4	4	4	4	4	2	2	4	4	4	4
V	4	4	5	5	5	4	2	6	3	3	3	6
CST	6	6	6	6	4	6	2	6	6	6	3	6
TD	4	4	4	4	4	4	4	4	5	5	4	4
FS	**43***	**43***	**45$**	**44***	**41***	**46$**	**34***	**47$**	**43***	**43***	**40***	**49$**

BP-Body parts, BK/T-Back/trunk (including lower back), UA-Upper arms, L-Legs, LD/F-Force/load, FS-Final score, LS-Left side, RS-Right side, N-Neck, PS-A-Posture score in Table A, TS-A-Total score of A, LA-Lower arms, W-Wrist, PS-B-Posture score in Table B, CS-Coupling scores, TS-B-Total scores of Table B, TS-C-Total scores of Table C, AS-Activity score, S-Shoulder, H-Hand, R-Rhythm, IOE-Intensity of effort, SA-Self-assessment, GR-Global risk, V-Vibration, CST-Contact stress, TD-Task duration

*-Medium risk, $-High risk, &-Very high risk

of WRMSD is found in the lower back, knees, legs (calf) and ankle/feet/toes as found in other studies also [9, 10].

The main cause of pain or discomfort in these body parts may be due to repetitive activities, working in squatting, kneeling and stooping position for a prolonged time, excessive pressure on the low back, knees, calf, ankle and toes, adopting awkward posture during working, improper and insufficient light, a requirement of precision in work, delicate material handling and working time. According to Cheraghi et al. (2012) working in kneeling push pressure on the knee, working in squatting push stress on tendons/ligaments/cartilage in joints and working in both causes knee disorders [11]. In the tilers' investigation for work-related musculoskeletal disorders, all the methods revealed that the tilers' are suffering from work-related musculoskeletal disorders while doing all task and further investigation and changes are needed.

All four methods used to assess tilers' posture show that tilers' are at high ergonomic risk, ranging from medium to very high levels of exposure. The results of all methods used agreed that the task considered for this study are at risk and need to take some measures to minimize WRMSD or related problems. Of all the methods,

the REBA methods showed that all tasks except 6 were at very high risk, while ERIN showed high risk for all tasks, and WERA showed the medium risk for all tasks except task 2. All methods showed significant results of risk for tilers'. REBA can evaluate the whole body, WERA can evaluate vibration and contact stress with other body parts. ERIN has also shown the potential to detect the risk level of the tilling work. All applied methods showed the ability to reveal the level of exposure in tilers'.

Tilers' should adopt some remedial action to minimize the problem. Tilers' should use some type of stool having wheels that will help them to sit in proper posture while doing tasks 1, 5 and 6. Tilers' should wear knee caps and hand gloves while working. To avoid straining the wrists and fingers, the tilers' should avoid putting the entire weight on the one (left) hand. Instead of getting up to pick up tile, tool or materials, tilers' should ask the helper to supply these. In all the locations, it is observed that the tilers' had worn plastic slippers while working that should be avoided and wear shoes. Tilers' should avoid placing the corner of tile on feet or plastic slippers which is very dangerous they should use some type of fixture to put the tile before placing. Tilers' should take a break every after 30 min.

4 Conclusion

The grievances of the tilers and scores obtained from OWAS, REBA, ERIN and WERA methods show that the tilers are at high ergonomic risk and suffering from work-related musculoskeletal disorders (WRMSD). From the analysis, it is observed that the lower back, knees, legs (calf) and ankle and toes are at high risk. The work-related musculoskeletal disorders are present in all five tasks mentioned above performed by the tilers and this is due to working in awkward postures, prolong squatting, stooping and kneeling and poor working place. The study also shows that the causes of WRMSD are not limited; the pace of work, the pressure of work completion and precision, support from colleagues, lack of education, information, training, individuals bad habits and ignorance toward health are other which add to this causes. This study revealed that further investigation is needed at the earliest.

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Determination of Effects of Instrumental Music on Brain Signal Using Electroencephalogram

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Abstract Music plays an essential role in every human being's life. It can stimulate the brain signal of human beings that are accountable for emotion, behavior, and cognition. This association of music with brain signals is the fundamental concept of musical therapy. Musical therapy is a recent trend in neurosciences that is highly beneficial for neurologically disordered patients due to its non-medicinal and non-invasive approach. As each music genre provides a unique change in the brain signal, music therapy utilizes various genres of music for different applications of treatment. This work has examined the effect of the instrumental music genre on human brain signals. Electroencephalogram signals from frontal, parietal, occipital, and temporal lobes during listening to flute and violin instrumental music has been recorded and analyzed to locate the changes in the cortical region. The outcome of this work will emphasize the advantages of the instrumental music genre for musical therapy.

Keywords Music therapy · Instrumental music · Electroencephalogram · Cortical region · Cognitive activity · Emotion

1 Introduction

Music engages in life of all living being's especially in human beings. When the music is listened, it stimulates positive effect on mood, behavior, emotion, and cognition. The music is processed in the human brain and this perception of music by the brain creates changes in the cerebral cortex. As each music comprises of different tone, timbre, rhythm and harmony, different genre of music creates different changes in the brain. When the music is played, the acoustic stimuli pass through the auditory pathway for which it initially enters the cochlea and later reaches the auditory cortex

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of the brain. The auditory cortex which is situated in the temporal lobe processes the tone of the music [1]. The planum temporale which is posterior to the temporal lobe, processes the elements such as timbre, syllable, and musical instrument that is involved in the music. The information carried in auditory cortex is correlated with information carried in sensory cortex at the temporal and parietal lobes. Likewise, this association applies for the musical information. The frontal lobe and parietal lobe processes harmony and rhythm respectively, thus these lobes are responsible for mediating working memory and behavioral response for any auditory stimuli. The insula which is situated deep inside the brain and between the frontal and temporal lobe is responsible for processing the cognitive information and emotion. Therefore, processing of music is engaged by several parts of brain. This makes the human to provide different response for different auditory stimuli. This property has been acted as the basis for musical therapy to treat neurologically disordered patients. Alzheimer's disease, autism, dementia, early stage of Parkinson's disease that are certain neurological disorders that are in need to improve the cognitive function [2]. Moreover, other mental disorder such as anxiety, depression [3] is in need to enhance the mood of the patient. In such conditions, musical therapy can be adopted that involves in improving the neuronal plasticity of patients without the need of any invasive treatments and without causing discomfort.

Musical therapy thereby enhances the human factors which include physical, behavioral, emotional, and cognitive activities that can improve the psychological (task performance) and physiological (health) activities of a human. Research studies have shown cognitive improvement with the presence of background instrumental music [4–8] or preferred music [9] and positive effect on mood with the presence of classical music [10, 11] which can be adopted for musical therapy. Mozart music i.e., from piano, classical music is mostly studied by many researches [12–14] and henceforth, very few studies have mentioned about the other instrumental music such as flute and violin on musical therapy. So, this present study concentrates on smooth instrumental music for which only flute and violin music is chosen since many studies have adopted instrumental music such as piano, classical, vocal, or favorite music [12–14]. Also, the neural response to instrumental music is being analyzed for three conditions such as before music (pre-music), during listening (music), and after music (post-music) rather than only during and after music. So, the change in neural activity in three conditions are studied in this work using alpha, beta and theta waves which can show the significance of listening to music on emotion and cognition. This study mainly focuses on frontal and temporal lobes as these lobes are associated with executive or cognitive functions (the memory, thinking, reasoning, and responding) and emotion [1, 15].

Consequently, this research study obtained the electroencephalogram (EEG) signals from the subjects while listening to either violin or flute music. The acquired EEG signals are analyzed, and the observed results are shown in below sections. The objective of this research study is to analyze the effect of flute and violin music on cortical region and to highlight the advantages of instrumental music on music therapy.

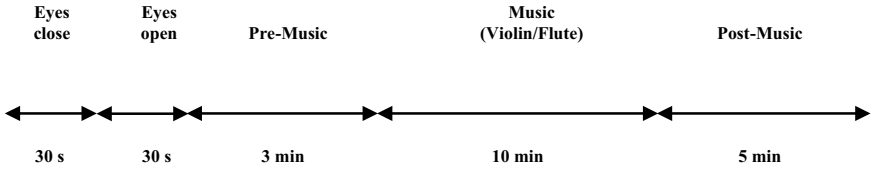

Fig. 1 Timeline representation of experimental protocol

2 Methodology

2.1 Experimental Protocol

In this research study, 5 healthy subjects in the age group between 24 and 40 have been participated. All the subjects are informed about the procedure before the experiment have started. The subjects are seated on a comfortable chair in the laboratory separately without any external disturbances. The subjects are instructed to avoid head movements, deep breath, and eye movement to prevent the movement artifacts. The total time of experiment conducted is 19 min. In the initial 30 s, the subjects are asked to close their eyes and in the next 30 s, the subjects should open their eyes to avoid the eye-movement related artefacts. Then, the subject should remain at rest position for 3 min during which musical stimuli has not been provided. Following to that, musical stimuli which can be either violin or flute music has been provided for next 10 min. At last, the subject should again remain at rest position for 5 min during which musical stimuli has not been provided. The timeline of experimental protocol is shown in Fig. 1.

2.2 Data Acquisition

EEG signals are acquired using EMOTIV EPOC + wireless EEG headset (Fig. 2).

Fig. 2 Experimental setup for EEG signal acquisition

EEG electrodes are placed according to the 10–20 international standard of EEG electrode placement on the cleaned scalp. EEG signals from temporal, parietal, occipital and frontal lobes channels with the reference A1 and A2 channels at the sampling rate of 128 Hz has been acquired while listening to music, before the musical stimuli and after the musical stimuli and the EEG signal from F7, F8, T7 and T8 channels has been considered.

2.3 Pre-processing

The pre-processing stage includes bandpass filtering and notch filtering of acquired EEG signals. All the pre-processing and EEG signal analysis are achieved using MathWorks MATLAB R2021a software. Butterworth bandpass filter of the filter order 5, in the frequency range between 0.05 and 50 Hz have been applied to remove the low frequency and high frequency components. The powerline interference at 50 Hz has been removed by the IIR notch filter.

2.4 Analysis of EEG Signal

The EEG signals before listening, during listening and after listening to musical stimuli has been applied with the wavelet packet decomposition (WPD) method. It is a multi-resolution, time–frequency analysis to obtain EEG sub bands such as alpha, beta and theta waves [16]. In WPD, wavelet coefficients are initially filtered, and it provides the equal width interval of filtered EEG sub bands i.e., the low frequency and high frequency components are uniformly filtered. This results in a smoother resolution of EEG sub bands. In this research study, Daubechies 4 WPD with the decomposition level of 7 has been utilized. The resultant theta, alpha and beta waves from WPD method are obtained from decomposition level 7, 6 and 5, respectively. Then the relative powers of each EEG sub band have been calculated [17, 18] to identify the changes in frequency components. Initially power of theta, alpha and beta band are evaluated, and the sum of the EEG band powers are also evaluated, and it is followed by the computing of ratio of particular EEG band (P_j) to the total EEG band power (P) to attain relative power (RP) of the particular EEG band as shown in Eq. (1):

$$\mathrm{RP} = P_j / \sum P \tag{1}$$

3 Results and Discussion

The EEG signals are acquired from the subjects before, after and during listening to music. WPD method has been utilized to obtain EEG waves and relative power of alpha, beta and theta has been calculated. The increase in relative power of beta indicates the increase in attention and thinking level [12]. The cognitive activity will be increased with the increase in relative power of alpha [13].

The theta wave activity is higher during music and post-music conditions at F7 channel. But no notifiable change is observed in F8 channel (Fig. 3).

The alpha wave activity is higher during music than pre-music and post-music at F7 and F8 location as shown in Fig. 4. The significant ($p < 0.05$) change has been observed in F7 location of beta wave activity (Fig. 5).

Theta wave activity is higher during music in temporal lobes (T7 and T8) compared to pre-music (Fig. 6).

During music, there is no substantial change in the alpha and beta wave activity at the temporal lobes (T7 and T8) and increase in beta wave activity is observed during post-music condition at temporal lobes (Fig. 7 and Fig. 8) also, significant ($p < 0.05$) change has been observed in T7 location.

As the temporal lobe and frontal lobe showed considerable activity of theta wave, especially after the music, it can be inferred that memory of music has been present even after the removal of music as mentioned in [19]. The alpha activity during music at the frontal lobe can be utilized in the cognitive activity study. The increased alpha and theta wave in this study during listening to music shows the enhanced positive mood on subjects as in the previous studies [16]. The beta wave has given significant

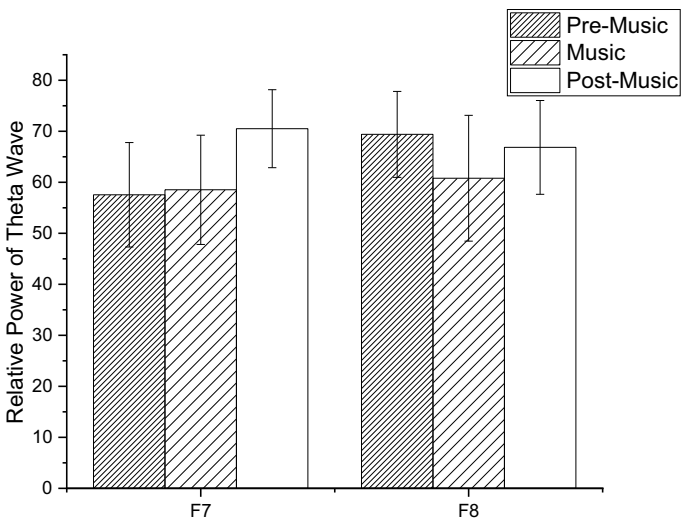

Fig. 3 Relative power of theta wave in during pre-music, music, and post-music groups at F7 and F8 location

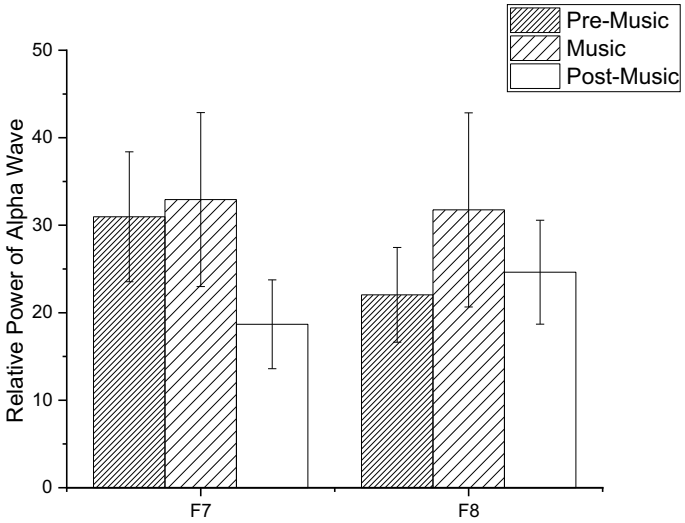

Fig. 4 Relative power of alpha wave in during pre-music, music, and post-music groups at F7 and F8 location

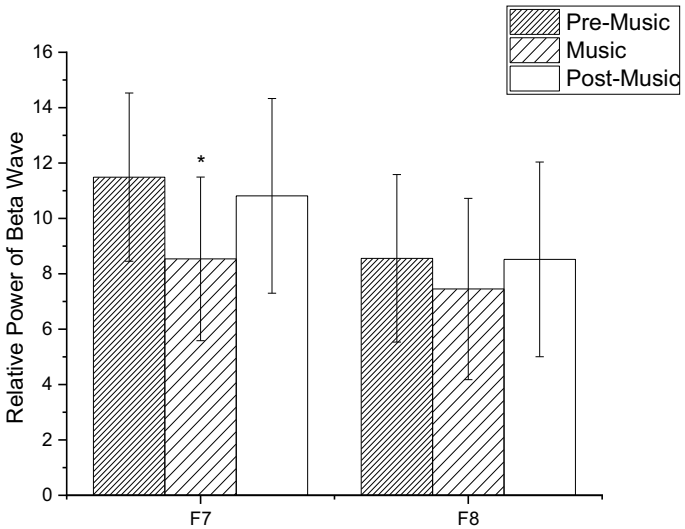

Fig. 5 Relative power of beta wave in during pre-music, music, and post-music groups at F7 and F8 location, *—significant, $p < 0.05$

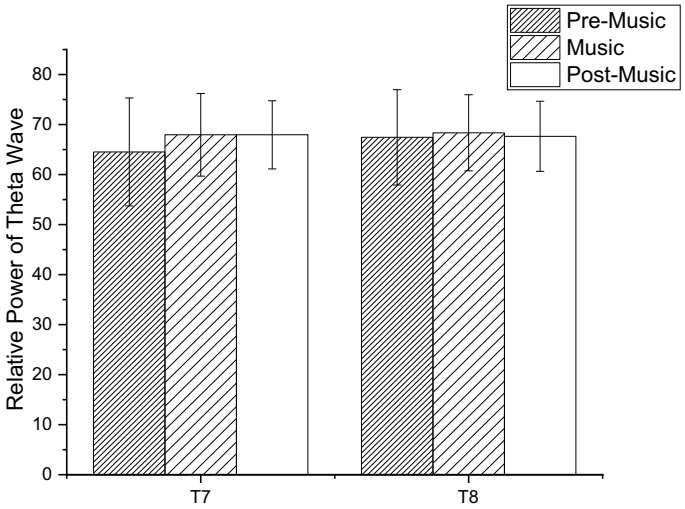

Fig. 6 Relative power of theta wave in during pre-music, music, and post-music groups at T7 and T8 location

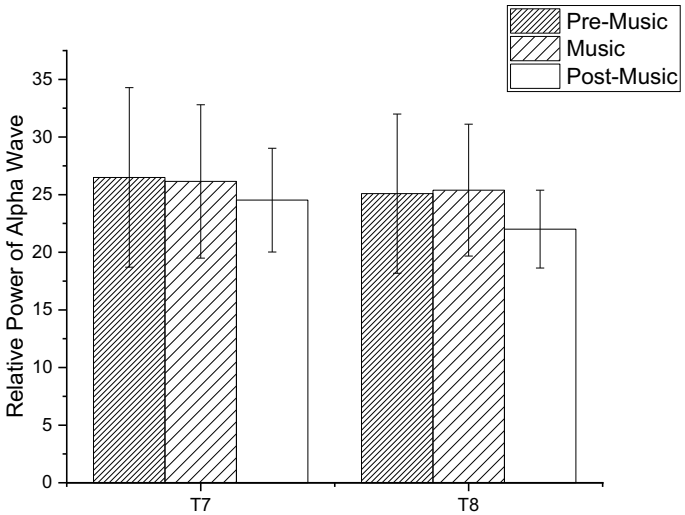

Fig. 7 Relative power of alpha wave in during pre-music, music, and post-music groups at T7 and T8 location

activity at the left hemisphere of the brain which shows that the subjects are attentive and their cognitive functions can be improved that corroborates with the previous research studies [20, 21]

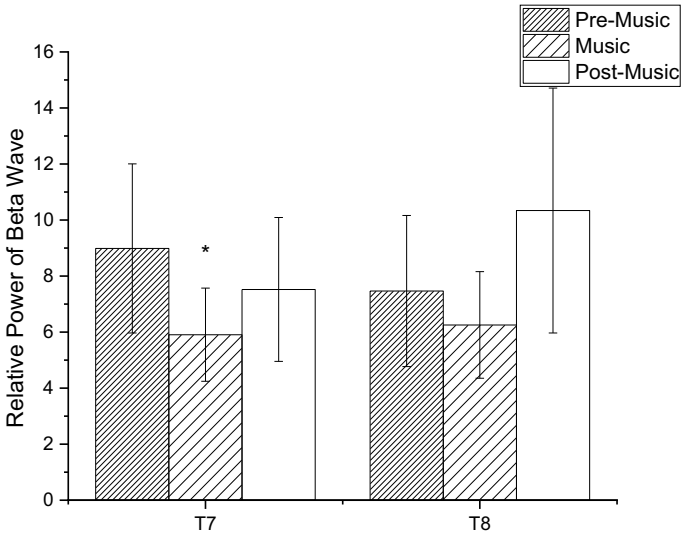

Fig. 8 Relative power of beta wave in during pre-music, music, and post-music groups at T7 and T8 location, *—significant, $p < 0.05$

4 Conclusion

Musical therapy is applied for the healthy subjects and their neural correlates are studied for determining the instrumental music effects in terms of emotion and cognition. The brain signal activity in the cortical region especially significant beta wave activity in the left hemisphere have emphasized the importance of instrumental music for the musical therapy on cognition. Additionally, the increased alpha and theta wave activity shows the enhanced mood on brain that is the improved emotion due to the instrumental music. Hence, by incorporating the instrumental music, the human factors such as emotion and cognition can be enhanced to achieve better psychological and physiological activities. This study has limitation on choosing the number of participants and failed to discriminate the effects of violin and flute music on brain signal. In future work, the significant instrumental music which is appropriate for cognitive improvement needs to be investigated and this study can be utilized for further analyzing the effect of musical therapy for neurologically disordered patients to enhance their cognitive functions.

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Development of Mastectomy Bra for Breast Cancer Survivors

Kritika Dhawan, Shivangi Sahni, and Manoj Tiwari

Abstract Breast cancer is the most common cancer among women in India, accounting for 25–32% of female cancers in all cities across the country. It is estimated that one woman is diagnosed with breast cancer every 4 min in India. Mastectomy is one of the most common cancer surgical procedures that cause a change in the look and shape of the breast. Eventually, it causes a major impact on a woman's self-image. Breast cancer surgery and treatment take both a physical and emotional toll. Post-surgery, women have to deal with another hitch in the pot—a lingerie wardrobe that no longer works for their new body. Thereby, generating a need for post-surgical products i.e. mastectomy bra and prosthesis as a part of the healing process and a return ticket to one's normal lifestyle. The research was conducted on a focused group of cancer survivors in India to develop a solution in the form of a mastectomy bra. The purpose of this research was to understand the challenges and the design requirements of breast cancer survivors concerning mastectomy bras. The user-centered design approach was applied to develop prototypes for a range of mastectomy bras based on information gathered through primary (interviews and diagnostic study) and secondary modes. In this research, four novel mastectomy bra designs were created addressing the needs of this very specific user segment. This research paper entails a step-by-step process of product development following a user-centered design approach. The research resulted in developing a satisfactory solution (mastectomy bra) for the users.

Keywords Breast cancer survivors · Ergonomic Mastectomy bra · User-centered Design (UCD) · Product development · Shoulder immobility · Body posture correction

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1 Introduction

Cancer is one of the leading causes accounting for 9% of deaths due to non-communicable diseases (NCDs) in India [1]. The latest report from National Cancer Registry Programme, India reveals that breast cancer is the most common cancer among women in India [2]. Breast cancer accounts for 14% of the cancers in Indian women [3]. According to the leading national newspaper the Times of India, every 4 min, one woman gets diagnosed with breast cancer, and every 13 min, one woman dies of breast cancer in India [4] making it the most prevalent cancer among Indian women. These huge numbers confirm the seriousness of breast cancer in India.

Mastectomy is one of the most common among cancers, causing a major impact on a woman's self-image usually linked with a decreased sense of femininity which leads to anxiety and depression to an extent that they avoid visiting public places [5]. Often in breast cancer literature what is said about breast loss is that women no longer identify themselves as "complete" or "whole" [6].

In looking well and normal, a woman represents herself as "recovered' [7]. Physical restoration of body image and wellness can be achieved through reconstruction surgery or by using a well-figured external breast prosthesis with an appropriate mastectomy bra [8]. These post-surgical products i.e. mastectomy bra and prosthesis play a significant role in the healing process for many women and act as a medium of return to a normal lifestyle. Bra needs of survivors are usually impacted by the post-treatment effects like discomfort from post-mastectomy pain syndrome, capsular contractures occurring because of scar tissue hardening, body imbalance, shoulder immobility, and drop.

Considering the importance of mastectomy bra in a survivor's life and the rage of breast cancer in India, mastectomy wear is the need of the hour. Surely, some sincere efforts and collective effort are required towards developing the mastectomy bra for the Indian survivors [9].

2 Concerns and Complications

The cancer surgery leaves perceptible if not noticeable changes within a woman's body [10]. The post-surgery treatments result in a series of anticipated changes in one's appearance. The surgical site is closed by stitches as a result bleeding could take place. While sometimes, fluid discharge also takes place that could lead to infection around the operational site. Sometimes, one is at risk of long-term swelling (lymph-edema) in your hand and arm after surgery. Once a patient has lymph-edema, it cannot be cured but early treatment can help to control it [11]. Post-surgery some women experience loss of body heat regulation, scabbing, blistering, skin loss, and formation of hard scar tissue (cording) in and around the site of surgery. "Fitting the task to the user" is an important consideration in ergonomic product designs. The cancer survivors have specific needs in terms of mastectomy bra as the body

is used to carry some weight on the chest area in form of the breast as that weight is removed from one or both sides, the body tries to compensate by rounding or bending the shoulders forward. This affects the posture due to the weight imbalance. Over time, this additional strain could result in constant pain and deformation of the upper body [18]. The amalgamation of all of these physical conditions can lead to unnecessary emotional suffering such as anxiety and depression [12, 13]. It also results in a challenge with comfort, aesthetic, and fit of the intimate wear post-surgery as women resume their daily living [14, 15]. This presents a challenge to the designers and establishes the need for an ergonomic product in the line with the specific user requirements.

In such scenarios, dealing with issues related to a mastectomy bra can further add to the misery rather than generating a sense of normalcy. Due to physical unevenness of the body, straps sometimes feel too tight, sometimes just slip off resulting in embarrassing events [6]. The change in shape, position, and consistency of breasts results in issues of mismatched cup sizes. Stitching in and around the cup also hurts or irritates breast scars [6]. Generally, it is found that the shape of the underwire is uncomfortable, it hurts or irritates due to scarring and damaged skin. Holding the mastectomy bra on the torso is a challenge as in comparison to the natural breast the prosthesis does not stay properly on the chest. As a result, the bra moves away from the chest wall. Also, the mastectomy bra catalogs lack a variety of styles, colors, and sizes and are generally seen as plain and drab. Due to the relatively small target consumer segment with specific production requirements, the cost of the product developed may be high. At the same time, the products with lesser cost may adversely affect consumer satisfaction [16].

3 Need for the Research

Breast loss is considered a loss of femininity [6]. Further, for some women, breast loss hampers the perceptions of self-image, self-identity, and sexuality and it physically impacts the body posture, also leads to deformity in the upper body [17]. According to Newman (2019), some women believe that wearing attachable nipples or breasts forms inside a bra can give the feel of having breasts and make them look normal, just like any other woman [18].

The products available in the Indian market lack to meet even the essential features, they resemble more like a normal bra with just added pockets while the truth is that the mastectomy bra is not just about the added pockets it has a whole lot of features such as good fit, broad under the band, soft breathable fabric, adjustable wide straps, wide pocket opening and many more that are equally essential to meet the comfort and needs of the survivors. Thereby, generating a need to fulfill user requirements in terms of feature and comfort at an effective cost.

4 Review of Literature

A good amount of research work has been undertaken on the social and psychological effects of breast cancer treatment, especially mastectomy. The clothing challenges that post-mastectomy women face have been discussed with focusing on the importance of clothing to accommodate the effects of the treatment [19, 20]. In 1985, a study was conducted by Rudd and Dodson, in which it was observed that depending upon the type of surgery, post-mastectomy women tend to develop some psychological and functional apparel needs [21].

Several pieces of research have been conducted by Feather and varying co-authors from 1988–1989 confirmed a significant relationship among importance of the clothing, clothing appearance satisfaction, and user's self-esteem. In 1989, Feather, Rucker, and Kaiser observed the application of apparel to cope-up with negative social associations of malignancy and deformations due to the surgical procedures. The bust emphasis, bare shoulders, and back closure were some of the issues observed with the clothing developed and making it difficult to use [22–25].

Dewsnap and Hart (2004) found that women no longer are fond of bra shopping due to a less variety of aesthetically appealing bras which are comfortable and have a good fit [26]. Gho, Steele, and Munro (2010) observed that problematic bra design caused difficulties in performing regular exercise [27]. The study was undertaken by LaBat, Ryan, and Sanden-Willin (2016) indicated that there is a need to put efforts on improvising post-surgery products such as mastectomy bra, prostheses, and lymph-edema sleeves or a switch to innovative approaches of product designing is needed for this particular category of products. It was established that the design of the mastectomy bra should be revisited. There is a need to work on developing new ways to provide support to the breasts when the bra and prosthesis are anchored on the torso [16].

Susanne Marie (2019) surveyed 62 survivors who have undergone double mastectomy with prosthetic reconstruction to understand their Bra preferences. Bra wing, strap, and under band comfort were found to be of critical importance to this group. Additionally, there is a need for well-fitting cups that hide imperfections, insulation (thermal comfort), moisture management, breathability, and adjustable straps [28].

A review of medical and design literature revealed fairly extensive research on survivors' satisfaction with prostheses and lymph-edema sleeves; however, limited research on satisfaction with mastectomy bras was found [16].

According to Beard (2011), recent trends in clothing and lifestyles present an opportunity for need assessment for design solutions to this exclusive target segment. With the diverse population of post-mastectomy women, there is a need for reassessment of clothing based on the requirement of this diverse population and redefining the design criteria for future prototype development [20].

4.1 User-Centered Design

Considering the high sensitivity and subjectivity of the research area it is essential to focus on the satisfaction of end-users concerning the product. To achieve a maximum level of satisfaction, the key is to be engaged in constant interaction with users to gain maximum inputs from them.

The participative User-Centered Design (UCD) approach is used in developing the solution. UCD is a design framework in which the needs, desires, and limitations of end-users of a product or service are considered at each stage of the design process [29–31].

The product development was undertaken according to the suggested five general stages of the UCD framework by ISO Standard 13407 (1999) [32].

4.2 Prosthesis

A prosthesis is a kind of detachable breast form that fits inside a bra. Alternatively, it can adhere to the skin creating the shape of a breast. Generally, the prosthesis is made from soft and lightweight materials such as silicone or foam. These prostheses come in different sizes, weights, and shapes, and can be customized as per the specific activity requirements [6].

4.3 Mastectomy Bra

A mastectomy bra is a specially designed bra with discreet pockets inside both the cup, which can hold breast prostheses in place for women who have undergone a mastectomy or a lumpectomy. They are specially designed bras with specific tailoring that accommodates the unique issues caused due to breast surgery [33]. It can be unilaterally pocketed, but mostly is bilateral.

5 Research Design

The research was initiated with a diagnostic study to understand the real issues, and to investigate survivors' awareness, need, and satisfaction related to mastectomy bras. Though a substantial amount of information was extracted from the review of literature, complete reliance on secondary information for such a sensitive and subjective topic was not enough. A questionnaire was developed to understand the actual scenario in terms of awareness among survivors, their needs, and satisfaction concerning mastectomy bras.

Locale. The survey was carried out in government, semi-government hospitals of the National Capital Region (NCR) of India, catering to survivors from different age groups, economic segments, and areas of India.

Sample Size. The Sample size of this survey was limited to 42 responses in total, keeping in mind the sensitivity of the topic, mental and emotional vulnerability of the survivors.

The next step included product development involving constant feedback from the participants and respective corrections. In this stage of product development, an "information-rich" pool of users through a purposeful sampling procedure was approached. Amongst the participants of the diagnostic study, who were already using the product were approached directly for consent to participate in a one-to-one semi-structured interview. The inclusion criteria were women who were already using the product and were comfortable in sharing their experience with the product. 10 women were willing to participate in the study. Also, a medical practitioner was approached to participate in the study, to understand medical aspects and all necessary information is covered concerning the product Thus, a sample size of 10 + 1 participants was obtained. Following which a one-to-one interview was set up. The questions covered in the interview focused on survivors' problems/challenges, experiences, and requirements for the mastectomy bra. The interviews were audio-recorded, transcribed verbatim, and analyzed using thematic analysis. The themes identified were bifurcated under two major topics as 1. Problems faced and, 2. Features required. Please refer to Table 1 for the broad themes.

After analyzing each participant's transcript, the data was sorted in tabular form and analyzed. It helped immensely in understanding the issues faced (with the existing product) by individual participants, and respective features required in the improvised product.

Table 1 Thematic analysis broad topics

Problems faced	Required feature
1. Less availability for plus sizes and small sizes 2. Strap too tight, end up digging in 3. The band of the bra is too tight and rides up 4. Lack of variety in styles and colors. Improper fit 5. Uneven look 6. Bra cup being small, edges of the prosthesis keep protruding at underarm and top of the cup 7. Closing the bra at the back is difficult. Scars are visible 8. Cannot wear sleeveless clothes because of straps visibility 9. The pocket opening is very small 10. Discomfort caused due to improper fabric 11. High product cost	1. Wide shoulder strap with cushioning 2. Broad and Adjustable bra band 3. Front closure bra 4. Full coverage 5. Soft, breathable, Stretchable fabric. Wide bra pocket opening 6. Variation in Design and colors 7. Adjustable bra straps 8. Availability of all sizes 9. Detachable straps 10. Possibility of bra extenders to be used

Table 2 Primary and secondary features of the product to be developed

Primary features	Secondary features
1. Soft, breathable, stretchable fabric 2. Front closure bra 3. Wide shoulder strap with cushioning 4. Broad bra under the band. Pocket inside both cups. Adjustable bra straps 5. Broad bra wing under the arm. Wide bra pocket opening 6. Variation in Design and colors	1. Detachable straps 2. Full coverage 3. Design similar to a sports bra. Seamless cups 4. Possibility for bra extenders

The next step included the development of a design solution (product development). The prime focus was put towards addressing as many user needs, ideas, and suggestions as possible for product development. The required features in the product were divided into two classes as 1. Primary features, and 2. Secondary features (refer to Table 2). Where primary features refer to the ones, which have high frequency and are accommodated in all the designs while secondary features, are the ones with low frequency and are accommodated in some designs only.

Post-development of the products, feedback from the participants was also taken to see the appropriateness of the developments, and accordingly, the products were finalized for respective wearers.

6 Product Development

The product development was done carefully considering the feedback of the participants in terms of primary and secondary features classification. In total 4 designs were finally developed as illustrated in Fig. 1. Bamboo Lycra blend (95% bamboo, 5% Lycra) was considered the most appropriate choice for the main body fabric due to its soft hand-feel, antibacterial properties, high absorbency, and thermal regulating properties. These properties are essential needs of survivors as they will help to cater issues like discomfort (itchiness) caused due to the harsh fabric around sensitive skin, during hot flashes, and excessive perspiration the high absorbing and thermal regulation properties of the bamboo fabric will help to absorb sweat much faster giving a cooling effect.

Design 1 is a fusion of front closure comfy racerback sports bra for overall support and posture correction. This design is a full coverage bra with front closure and adjustable back closure keeping in mind the concern related to shoulder immobility and ease in overall bra adjustment for the user. It incorporates seamless molded cups to hide the inconsistencies in breast shape and size. An extended seamless molded bra pockets were formed to make sure no stitches were done around the surgical site to avoid irritation. A broad under band was used to provide firm support to the breast and prosthesis. Wide shoulder straps with cushioning were constructed to distribute

Fig. 1 Prototype development

the pressure. Also, the straps were made adjustable using loops at the front for better comfort and fit which can be easily adjusted by the user.

Design 2 the second design is inspired by a sports bra with a wide adjustable under the band. One of the major issues with a typical sports bra is tight under the band. With this design, we aspire to solve this major issue for the users with an adjustable under the band. This design is a full coverage bra with front closure solving the concern related to shoulder immobility and wide adjustable under band to provide firm support to the breast and prosthesis, achieved with an adjuster placed at the back with a procedure to be closed at the front. It incorporates seamless molded cups with an extended seamless molded bra pocket, to make sure no stitches were done around the surgical site to avoid irritation. Wide shoulder straps with cushioning were constructed to distribute the pressure. In addition, the straps were made adjustable using a hook and eye pair at the front for better comfort and fit; they can be easily adjusted by the user from the front.

Design 3 The third design is inspired by the need of today's women who wear western clothing quite often and would prefer to wear a bra with strapless or interchangeable bra straps. This design is an extended demi-cup bra with front closure, and adjustable back closure for ease in overall bra adjustment for the user, keeping in mind the concern related to shoulder immobility. It incorporates seamless preformed molded demi cups which are extended using body fabric for good coverage and to hide the inconsistencies in breast shape and size. This design also contains seamless molded pockets with a wide under band to provide firm support to breasts and prostheses. Wide shoulder straps with spacer fabric cushioning in the front and elastic

adjustability at the back were constructed to adjust and distribute pressure. Also, the straps were detachable and interchangeable as per the requirement of the user. U-back was provided at the back with an adjustable hook and eye for additional ease, fit, and comfort. This back hook and eye adjustment can be made by the user before wearing the bra.

Design 4 the fourth design is an everyday comfy leisure bra with full coverage and front closure. This design has a single seam contoured cup with scalloped lace detailing around the neckline and front closure, keeping in mind the concern related to shoulder immobility. It incorporates single seam contoured cups made using a combination of body fabric with lace details for the upper panel and soft Lycra fabric on the bottom panel to hide the inconsistencies in breast shape and size. It contains seamless extended molded bra pockets to avoid irritation around the surgical site. Wide shoulder straps with cushioning in the front and elastic adjustability at the back were constructed to adjust and distribute the pressure. U-back was provided at the back for maximum support and posture correction.

7 Results and Discussion

The results of the diagnostic study confirmed that the majority of survivors were aware of the mastectomy bra. While the mode of awareness was NGOs/Support groups for maximum survivors followed by family/friends and doctor/physician, from this it is evident that NGOs are working quite actively to spread awareness about the mastectomy bra. Another important conclusion that can be drawn regarding the awareness of the product is that level of education plays no significant role in one's awareness as for maximum survivor the mode of awareness was via secondary sources not by ways of self-awareness thus one's education qualification could not be related to the awareness of mastectomy bra. How much time has passed to the surgery can be seen affecting the awareness level among survivors because after a while, they tend to develop a need for a product to meet multiple requirements. Every survivor irrespective of the fact that whether they were aware or not, uses it or not, but thinks that a mastectomy bra is a need and should be available in the market. Another important finding regarding how many of the survivors are using the product, 87.8% of the ones having access are using the product and the remaining 12.2% don't use the product even after having access to it. When looking at the price range of the product, the maximum number of people are getting the product free of cost through NGOs followed by a range of INR 300–600. The study shows maximum survivors prefer to wear a mastectomy bra regularly, thus the comfort of the product is very important. Also, the rate of satisfaction with the product is not very high because the majority thinks that there is a lack of comfort, followed by quality issues. Thus, there is scope for improvement or the development of a new product in this segment.

The thematic analysis was conducted based on the two bifurcations as "Problems faced" and "Features required". Please refer to Figs. 2 and 3 for a graphical representation of the responses.

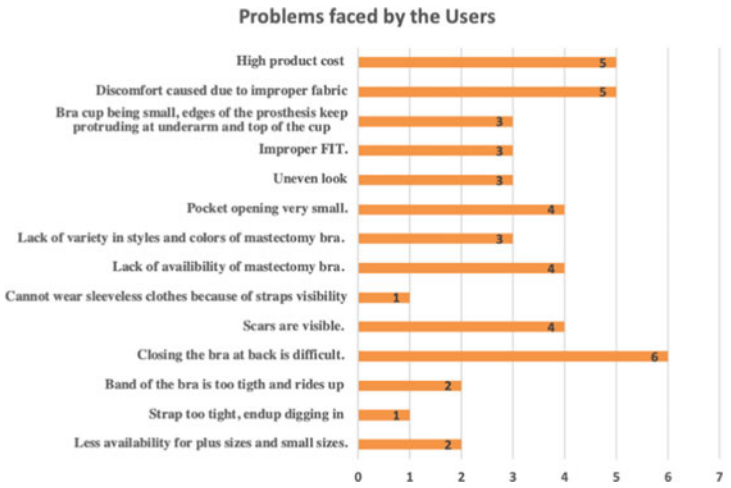

Fig. 2 Thematic analysis: Problems faced by users

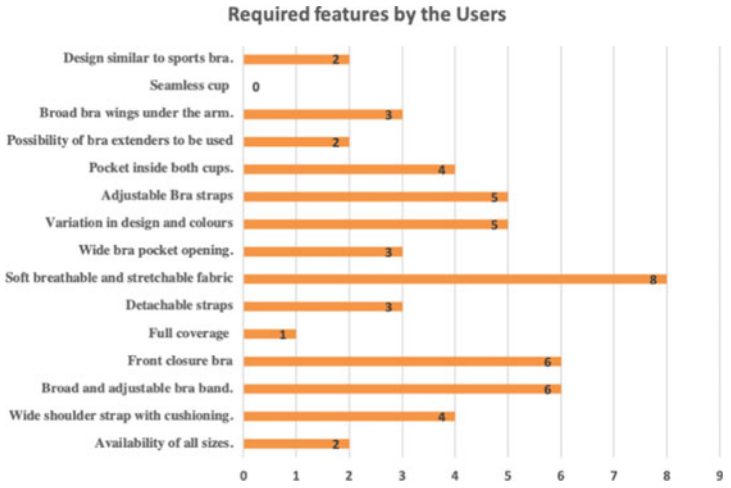

Fig. 3 Required features by users

Primary and Secondary features to be considered for the product were determined after the thematic analysis. Table 2 indicates the primary and secondary features based on that a range of 4 unique designs was developed. Further 2 samples of each design were distributed among 8 participants and were evaluated on the basis of participants' comments on each parameter using the feedback form. The parameters for evaluation were Support, comfort, fit, fabric breathability, ease of inserting prostheses, arm mobility, overall bra adjustability, aesthetic and overall shape. For Design 1 support, comfort, fit, fabric breathability, and overall bra adjustability an average rating of 4/5

was received. While other parameters received an average rating of 3/5. For Design 2 support, fit, fabric breathability, ease of inserting prostheses and arm mobility received an average rating of 4/5. While the rest of the parameters received an average rating of 3/5. For Design 3 fit, fabric breathability, arm mobility and aesthetics and overall shape received an average rating of 4/5. While the rest of the parameters received an average rating of 3/5. For Design 4 all parameters except overall bra adjustability received an average rating of 4/5 and overall bra adjustability got 3/5.

8 Conclusion

This study highlights the needs and desires of the survivors and aims to provide a homegrown solution to the perfect mastectomy bra. The research results from this study validate that there is not likely to be one bra that will meet the wide variety of needs and desires presented by this particular group of users. Hence, all four novel bra concepts were approved and developed according to the wearers' requirements. The products developed through this study may help in the rehabilitation of survivors and boost their morals by resolving the issues faced by them physically and emotionally. This study provides evidence that having bras designed to accommodate the physical differences that persist after a mastectomy is of value to the consumer in this very specific user segment. This study also has practical implications for bra manufacturers planning to enter or expand their range for mastectomy bras as it provides all the necessary information to cater to this very specific user segment.

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Working Posture Evaluation of Bus Drivers—Using CMDQ and RULA Technique

Soumyajit Das, Sujit Patra, Subir Danda, Bivash Mallick, and Avishek Pandey

Abstract Work-related musculoskeletal disorders (WMSDs) are the major issues in various fields of work. But the same is more prevalent in the case of heavy vehicle driving. It has been noticed that multiple studies on WMSDs had already been carried out on heavy vehicle drivers abroad. However, those ergonomic interventions failed to provide any directives to make the driving a safe and pleasuring task. In this scenario, the intensity of musculoskeletal problems associated with bus driving and other critical issues influencing automobile driving have been evaluated to suggest suitable remedial measures. The study focuses on the psycho-physiological aspects of a bus driving through the ergonomic intervention of driving posture and driving seat. By which it assesses the degree of musculoskeletal symptoms on various body segments and their frequency. The study includes follow-up studies on long-term muscular disability among bus drivers (n = 32) and questionnaire studies on the prevalence of back pain. Their driving postures have been captured video- graphically, subsequently analyzed by Rapid Upper Limb Assessment (RULA) technique. Before that, Cornell Musculoskeletal Discomfort Questionnaires (CMDQ) were used to collect data regarding musculoskeletal health information of the bus driver. A vibrant co-relation has been observed between the outcome data of CMDQ and RULA. Results yield that the various body segments, such as the lower back, neck, upper arm, lower legs and wrists, are prone to musculoskeletal disorder due to prolonged exposure to bus driving. Analyzed data suggests that the re-location of control elements is ultimately a remedial solution for the drivers by modifying the working environment ergonomically.

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1 Introduction

In our developing and competitive world, the automobile transport system plays an important role. It is acknowledged that India is a vast country with a population of 1.2 billion individuals [1]; it is clear that community transportation plays a vital part in the Indian economy. The utmost population embraced the poor and middle class, which displays that public transport is the primary means of travel. Therefore, manual-handled vehicle drivers are involved in a highly anticipated job where both passengers and goods are carried in minimal time. Bus drivers are essential professionals in the present culture, as they conduct thousands of travelers to their target. The average pace of development of the metropolitan population has not been relied upon to change fundamentally during the following ten years or somewhere in the vicinity. Accepting a decadal increment of around 32%, India's metropolitan population must increment from 377 million every 2011 to 500 million in 2021. As far as the level of an entire population, the population in metro cities has gone up from 17% in 1951 to 31.8% in 2011 and is relied upon to boost up to around 35% by the year 2021 [2].

There is a high risk possess by bus drivers; who are experiencing muscle aches and pains in certain body parts due to incorrect posture and prolonged or uncomfortable sitting positions [3]. Poor ergonomics in the bus driver's work environment, which is intended to give the planned city and regional authorities a wide increase in physical and psychological stress on the driver [4]. Based on the 2019 NIOSH Occupational Accident and Disease Survey, heavy automotive industries such as trucks, buses, and real vehicles are at risk of illness, injury, illness, and relative work and time-related obligations. Lifestyle and other issues.

There is subjective evidence that drivers usually have musculoskeletal disorders (MSD), [3, 5, 6], but the psycho-physiological aspects have not been investigated. While several studies have examined motorcyclists' work-related issues to determine the risk factors and pervasiveness associated with MSD, none have explicitly focused on the physical-mental relationship.

There are various reports on the high occurrence of business-related musculoskeletal problems like WMSD, particularly low back torment in various word-related gatherings adding to enormous financial misfortunes to people just as to the local area [7]. It has shown that driving can prompt musculoskeletal issues, and drivers are exposed frequently to postural pressure encouraging back neck and furthest point torment in their workplace [8]. A report also noticed that working public travel vehicles in metropolitan communities might be among the most upsetting and undesirable of present-day occupations, and it has been shown that proficient drivers have a higher commonness of word related problems than do other word related gatherings [6, 9, 10]. Work-related complaints of the musculoskeletal system are influenced by somatic and cognitive risk factors. Several physical aspects can

contribute to increase the musculoskeletal pain and physical strain of bus drivers, leading to fear and malaise [11]. Bus drivers experiences various types of musculoskeletal problems among which, low back pain has been increasingly reported in previous studies [9]. A study [12] provided an overview of the incidence of low back pain among transport drivers, porters, and stationery specialists. They found that 81% of American drivers and 49% of Swedish drivers had a low back torment. The creators additionally detailed that transport drivers had the most elevated danger of low back torment among the three word-related gatherings. Past investigations similarly revealed that male transporters were multiple times more than any other probable stationary specialists to build up a herniated slip disc [11, 13, 14].

The typical cause of work interruptions for bus drivers is usually supported by some external problem. At the same time, improper posture is an intrinsic aspect that may be caused by the individual's lifestyle, often seen as suffering, rigidity, rigidity, enlargement, redness, tremor, and death [15]. Physically, the most commonly affected areas of the body are the spine, neck, forearms, shoulders, and fingers, although recently more attention has been paid to the lower limbs such as the lower back, thighs, ankles and knees [16–18]. Other reasons can be categorized as professional and non-professional workers. On behalf of the work-related cause, risk factors for the frequency of musculoskeletal disorder can be individual factors such as gender, age, anthropometry (weight, height, and metabolic rate) are highly influential [19, 20]. Some ergonomic tools used to do the primary survey, the occurrence of musculoskeletal disorders is the Nordic musculoskeletal Questionnaire (NMSQ), CMDQ, and RULA [21]. To evaluate drivers' cabins, the design of the seat ergonomically plays an essential factor. The degree of discomfort is directly influenced by seating ergonomics. The Cornell Seating Evaluation Form gave a prominent concept about operators' area of discomfort against various factors, such as Level of seat comfort, Degree of chair adjustment, Ease of use, the proportion of body support, and overall seating experience [22].

This study aims to find the musculoskeletal disorders of passenger bus drivers in semi-urban areas and to analyze in depth the prevalence of musculoskeletal disorders and psychophysical aspects by recording the movement of the bus driver's work processes. In particular, the degree of musculoskeletal indication in the different body segments and their frequency should be investigated.

2 Methodology

2.1 Subject

To administrate a survey on the Local Bus Driver, this study firmly chose a semi-urban region of India. The study considered Haldia to Mecheda Bus route, which is around 48 km distance. Figure 1 showed the selected part for this study. The area is

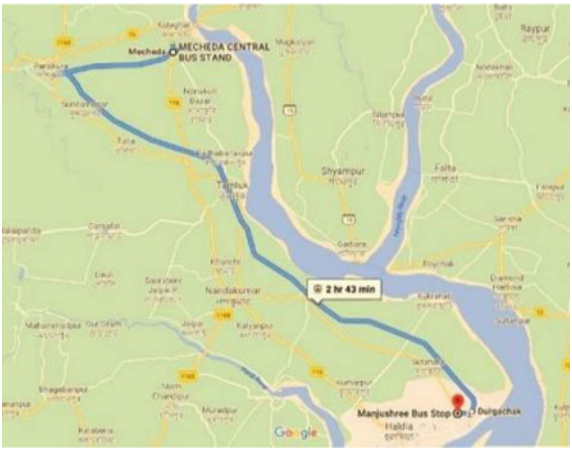


Fig. 1 Haldia to Mecheda Bus route (selected region)

alongside Hooghly and Rupnarayanpur River and having a vast number of automobile transport daily. Due to Industrial belt traffic congestion are high enough and time is taken to reach bus terminus also varied. The participants for this study were drafted through the Bus Transport Union of Haldia, and bus drivers were considered based on commercial vehicle authorizations issued by the Indian government. Subjected drivers were inner-city transport with minimum one year experience. They had no major alarming injuries to their musculoskeletal systems (e.g., significant ruptures, abstraction of the congenital limb, lower limb, or spine problems). The survey questionnaire has been validated, and all participants had to sign an informed consent form. 32 numbers of respondents participated in this study. Full time bus drivers are only enrolled for the current examination, as the current study considered the WMSD in this specific kind of driver.

2.2 Study Design

The aim of this study was to demonstrate the prevalence of muscle problems in bus drivers and to assess possible ergonomic or physical aspects that might contribute to these complications. Participant drivers were interviewed in person, followed by a physical examination. It is planned to obtain information about the characteristics of the driver and physical activity, as well as to study the prevalence and types of musculoskeletal disorders in different areas of the body and related diseases. The ergonomic factors chosen for this study were built on a review of previous research [10–12, 22]. The physical assessment provided quantitative methods of some frequently observed variables such as seat arrangement, body movement during driving, which may have

Fig. 2 Commonly Adopted Driving Posture of Bus Driver

some relationship to the various regions of musculoskeletal awkwardness. Additionally, gathered the exercises of the bus drivers through observations and the utilization of a camera. Also determined the probable reasons for having trouble with the different body parts were through verbal conversation (Fig. 2).

Moreover, the anthropometric approximations of the driver's working atmosphere were likewise accumulated to observe whether the measurements are inside the anthropometric guidelines.

2.3 Questionnaire Survey

A set of questions was used to investigate drivers' backgrounds such as exercise habits, financial status, numbers of dependent individuals, alcohol consumption, work satisfaction, and work environment. In addition, the participants were questioned to determine the degree of risk in several body parts according to the determination of the level of danger while driving a car with the help of the Cornell Musculoskeletal Disorder Questionnaire (CMDQ) [23]. A body map illustration was also picturized along with the CMDQ questionnaire. It questioned the frequency of body pain, the degree of discomfort drivers experienced, and intervention of despair into their jobs. Cornell Ergonomic Seating Evaluation Form (v21) [24] was also evaluated to analyze the seating ergonomics for bus drivers on a 10-point scale. The assessment format depends on those inquiries that are most distinct between seats (or sitting experience) and those that find with ergonomic proposed observations. This study also surveyed high-risk postural through Rapid Upper Limb Assessment (RULA) [25] to calculate the musculoskeletal loading of upper extremities.

2.4 Data Analysis

The chi-square test was used as a statistical survey in the following comparisons: (a) years of driving in relation to age; (b) the age of the respondent until the emergence of SMEs; (c) the driving year of the respondent with respect to the emergence of SMEs; (d) Body parts with MSD in old age.

Surveyed data were subjected to statistical tests used Microsoft Excel.

3 Result

3.1 Demographics and Work-Study

Overall, 36 surveys were done. All the drivers are male; no female candidate was observed on this surveyed route. Of the participants, 32 (88.89%) were currently working as a bus driver, and 4 (11.11%) were no longer working as a driver. Hence, that 11% were exempted from our study. The mean age of participants was.

41.78 years, with a range of 22–71 years of age. The physical height of the drivers was 168.34 cm (with a range of 159–177 cm.). The mean qualification of the drivers is 7th standard, with a range of grade 3 to grade 10. Participants had worked in spay-neuter for a mean of 9.7 years of driving experience (range 1–25 years). The drivers have a mean monthly income of Rs. 12,500 with a standard of family members of 4 persons.

Drivers were spent approximately 15 h per day with a minimum level of work stress. A few drivers (8.34%) rarely got stuck in Police cases due to disobeying the traffic laws within a week. Mainly the surveyed bus drivers involved of Male aged 33–45 years and over and 11–20 years of driving experience. Table 1 shows the relationship between driving year and the driver's age.

Occurrence of muscular disorder categorized as Low, Medium, and High. According to such rating, drivers rate health-related issues against their feel about pain. The numbers of drivers' pain are recorded in Table 2.

Table 1 Relation between years of driving to age

Years of driving	Age range				Total
	20–32	33–45	46–60	Above 60	
Below 5 years	2	6	0	0	8
5–10 years	3	6	1	0	10
11–20 years	1	7	4	0	12
Above 20 years	0	0	1	1	2
Total	6	19	6	1	**32**

Table 2 Relation between duration of driving to the occurrence of disorder

Driving years	Occurrence of MSD		
	Low (1)	Medium (2)	High (3)
Below 5 years	5	2	0
5–10 years	1	5	4
11–20 years	3	4	6
Above 20 years	0	1	1

Table 3 Relation of age with the occurrence of disorder

Age range	Occurrence of MSD		
	Low (1)	Medium (2)	High (3)
20–32	4	2	0
33–45	4	7	8
46–60	2	2	2
Above 60	0	0	1

To analysis about the relationship between musculoskeletal illness and the age of the drivers. Table 3 shows a correlation of age with the occurrence of Disorder.

3.2 Prevalence of Musculoskeletal Discomfort

a. Evaluation of Body Comfort through CMDQ-Body assessment:

Out of 32 participants, 29 drivers (90.62%) reported muscular problems on several body parts. Lower Back (35.9%), Upper Arm (15.3%), Lower Leg (11.9%), neck (9.6%), Wrist (8.4%) were mainly affected for the drivers. Over 50% of drivers facing wrist, Upper Arm, Neck, Lower Leg, and upper back discomfort recognized their discomfort entirely to their work, and 89% responded Lower Back injury. Overall, participants attributed 92% of reported cases of MSD entirely. Figure 3 depicts the study of the prevalence of aches on various body parts and highlights risks in percentage.

b. Ergonomic Seating Evaluation form:

From Fig. 4 it is noticeable that the Criteria of chair adjustment and Degree of body support were rated as significantly low enough.

c. Rapid Upper Limb Assessment Evaluation:

Figure 5 shows the resemblance of the RULA score with the affected various body region. The average for the trunk body region was equal to 2.47 (14.95%), which was moderately significant compared to a maximum score of 6, while there is an essential mean score for the wrist, 2.89 (17.50%). This imply that the necks and the wrist of the

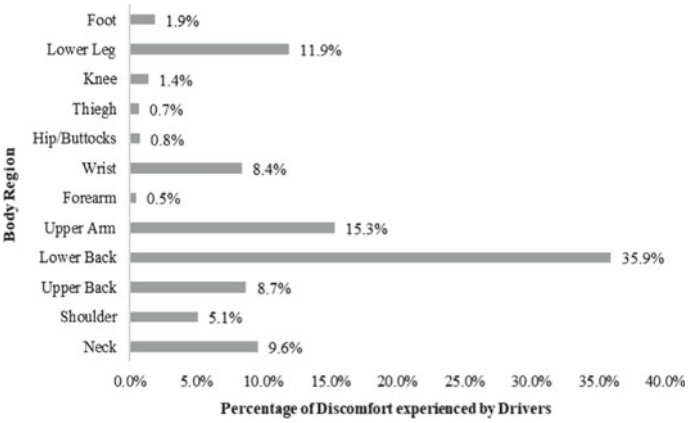


Fig. 3 Prevalence of disorder for the body region

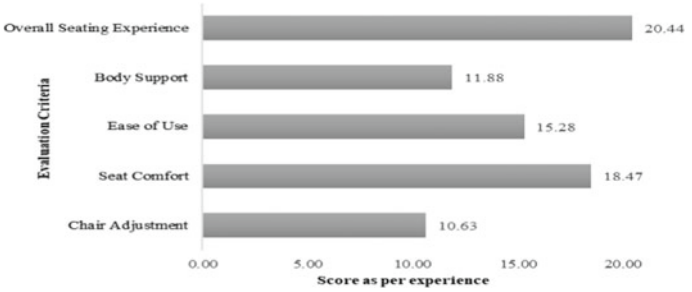
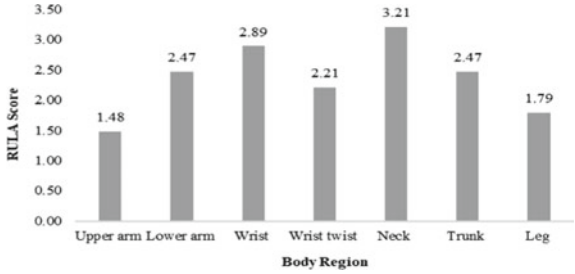


Fig. 4 Ergonomic seating evaluation

Fig. 5 Ergonomic risk assessment on several body parts (postural analysis score)



bus drivers were in, side bending or twisting positions while performing the task. The mean of the lower arm is 2.47 (14.95%) in contrast to the highest score of 3, while the upper arm is equal to 1.48 (8.96%). As demonstrated that the upper arms were in flexion less than 20° and up to 90°, and the lower arms were in flexion between 60° and 100° or in flexion between 20° and 45° with their shoulders rising or upper arms were abducted. The trunk means a score of 2.47 (14.95%) with the maximum

Table 4 Summary of RULA analysis

RULA analysis				
Upper arm	Left	**2**	Neck	**3**
	Right	**2**		
Lower arm	Left	**2**	Trunk	**2**
	Right	**2**		
Wrist	Left	**3**	Leg	**2**
	Right	**3**		
Wrist twist	Left	**2**		
	Right	**2**		
Muscle			**1**	
Force			**0**	
RULA grand score			**6**	

of showed that the wrists were inflection degree up to 15° with bending away from the mid-line or the degree of flexion was not more than 15° in operation. The mean leg score was 1.79 (10.84%), with a maximum score of 2. This also indicated that the position of the legs in the observation was in an even equilibrium posture, or there was no proper support for legs.

Mean RULA score summarized on a tabular format, where exertion of an external force taking constant (equal to 0). Moreover, for work-related muscle score was also taken 1, which is significant for the study. As displayed in Table 4, the reported RULA Grand score 6.

3.3 Psychological Factor

Participants were mostly reported that they were "satisfied" with their work (93.7%), percentage of them have enjoyment of their work (87.4%). Their family members were also gratified (68.7%) about their earnings. Very few volunteers have reported being "unsatisfied" with their job experience (6.3%). Some (12.5%) drivers felt mental stress during the operation due to road conditions, engine vibration, suffocation due to pollution, or poor design consideration. The rest (87.5%) did not find any mental stress during driving.

4 Discussion

The relationship between years of driving and age shown in Table 1 shows that years of driving also increase with age. This shows that the age of the driver is statistically related to years of driving, with a chi-square value of 0.02. On the other hand, as shown in Table 2, most drivers experienced a higher degree of MSD correlated to their driving experience (chi-square value = 0.106). Table 3 depicted that majority of the drivers are of age group from 40–60 years who experienced MSD, with driving experience of 11–20 years. However, 15.6% of drivers (5 out of 32) also experienced a significant level of physical injury within their early stages of driving. This means that the occurrence of the muscular disorder can be revealed at any age level.

From the Cornell Musculoskeletal Disorder Questionnaire survey, the result indicates that several body parts, such as the Shoulder, Back, Upper Arm, Forearm, Wrist, Hip/Buttocks, were affected due to poor ergonomic consideration. CMDQ-body assessment results shown in Fig. 3, the degree of risks to the drivers, and a corresponded graphical representation showed the higher order of stress generation on different body portions during driving. As shown in Fig. 3 higher degree of discomfort was reported on the Lower Back (35.9%), which may occur due to the poor design of the seat. Other body regions such as the Upper arm, Forearm, Shoulder muscle are hampered because of extended body posture [26]. However, Fig. 4 depicted the seating discomfort level of significance, where the focus should be taken on body support and adjustment of drivers' seats for design. Mean seat comfort and ease of use score lower than the other factors, which should be modified in contrast to postural analysis. Cornell Seating Evaluation form underlined that arm support adjustability, degree of armrest comfort, depth of seat pan, support of armrest height were an unacceptable range.

RULA score for neck, wrist, lower arm, and trunk muscle showed a higher risk of injury for the drivers, as shown in Fig. 5. Regular exercise and maintain work-rest may solve such postural and muscular stress [27, 28]. From Table 4, RULA means score for upper arm and lower arm (both left and right) as 2 due to bad arm posture. It generally occurred because of anthropometric measurement of the driver and bad cabin design [29]. Drivers' wrists were twisted several times during driving, and fingers were also used several times for pressing the horn. The mean neck score was reported as 3, which is moderately high. The bus drivers twisted their neck posture to check mirror-view as well as communicate with passengers sometimes. Legs of drivers were also not supported enough and faced high risk (score 2). Body muscles were mainly static and repetitive use them. Due to the above reasons, RULA Grand score calculated as 6 exhibited that the drivers' work-stations have to be investigated further and changes should be effected immediately. The drivers' improper body posture may lead them to have musculoskeletal pain as per our analysis and it seems they are displeased with their job. But in reality, they (bus drivers) rarely focus on this aspect, as driving is their only means of livelihood; they seem satisfied by their work and neglects their pain for their earning (monetarily satisfied). Even very few of them ever think about their body posture while driving before our questionnaires.

Due to the increase in need of the family, many bus drivers prefer to have high working hours. As they were able to satisfy their family needs, thus their high working hours had less impact on their working psychology which was suppressed by economic benefits. This research could further be extended by considering these factors.

5 Conclusion

This study aims to determine the musculoskeletal disorders of bus drivers in Haldia and conduct an in-depth analysis of the causes of postural muscle disorders to assess the performance of bus drivers. The study highlights that age, driving age, the incidence of muscle injury are significant and drivers in some areas also experience physical pain. The results of the RULA indicate that the current practice of bus drivers needs to be investigated further and changed immediately.

This study aims to determine the musculoskeletal disorders of bus drivers in Haldia and conduct an in-depth analysis of the causes of postural muscle disorders to assess the performance of bus drivers. The study highlights that age, driving age, the incidence of muscle injury are significant and drivers in some areas also experience physical pain. The results of the RULA indicate that the current practice of bus drivers needs to be investigated further and changed immediately.

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Quantitative and Qualitative Study on Lifestyle of Polycystic Ovarian Syndrome or Disease (PCOS/PCOD) Patients

Yagnesh Gohil and Puneet Tandon

Abstract Polycystic Ovarian Syndrome (PCOS) is a common condition in women nowadays. The previous studies show its direct correlation with infertility, type 2 diabetes, heart disease, and other major illnesses. This study aims to give a detailed understanding of PCOS quantitatively and qualitatively. The study began with interacting with three reputed gynaecologists, to understand PCOS and other related complications. Later, a survey on PCOS of 43 random women was undertaken to quantitatively analyze the data. Further, four participants expressed interest in a detailed qualitative interview. The questionnaire for a qualitative study focused on the parameters like time since PCOS was diagnosed, symptoms, relation with diabetes, stress, medicine, diet, exercise, the reason for neglecting doctor's advice, etc. All the insights were mapped out on a white canvas to find out the patterns, their pain points, as well as gain points. Out of 43 patients, it was diagnosed that 18 females were suffering from PCOS. Out of 18, more than half of the participants followed the advice on diet control but they followed it blindly. Those four interviewed participants stated that they had diabetes in their family background and due to PCOS, they could be more prone to be diagnosed with type 2 diabetes. The study opens up many opportunities for the design intervention on a domain that is critical but often neglected due to unawareness. This research on PCOS patients' mindset and behaviour towards managing PCOS may become an important resource while ideating on the solution to the identified problems.

Keywords Polycystic ovarian syndrome or disease · Qualitative research · Quantitative research · Infertility · Lifestyle · Diet and exercise

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1 Background

The ovaries of a woman play an important role in conceiving a child. Ovaries are part of the female reproductive system. The pituitary gland of a woman stimulates two hormones Follicle Stimulating Hormone (FSH) and Luteinizing Hormone (LH). In the first 15 days of the cycle, FSH and LH are being flowed into the ovaries, which results in follicle production in the ovaries. It converts immature eggs into mature eggs and increases the size of the follicles. After 15 days, the pituitary gland releases the surge of LH that causes the most mature follicles to open and release eggs, which eventually leads to ovulation. Other remaining follicles dissolve automatically. It is the normal menstrual cycle [1].

If one has PCOS, the pituitary gland releases an abnormally high amount of LH into the blood system. As a result, follicles do not mature and ovulation does not occur which can lead to infertility. Some of the immature follicles do not dissolve and it remains in the ovaries as a cyst. In addition, one can have a high amount of insulin in their blood with this condition. Too much insulin combined with high LH can lead to excess production of the male hormone testosterone. A high level of testosterone also prevents ovulation and leads to infertility. A high level of testosterone can cause some issues in the female body such as facial hair growth in male patterns, acne, and weight gain. PCOS raises the risk of having diabetes, high BP, bad cholesterol, and heart failure [2].

In 2011, a study showed that 10% of Indian women were having PCOS in India [3]. This number has increased of late and currently, one in 5 women is suffering from PCOS, according to one of the gynaecologists we had discussed the issue in detail. The previous study also showed that PCOS patients are more prone to be diagnosed with Type 2 diabetes [4]. One of the previous studies concluded that a future study should focus on the effect of lifestyle by observing different characteristics and behaviours of PCOS patients [5].

It is noticed from the secondary research that understanding the mindset and behaviour of PCOS patients is vital before providing any solution. The core belief of this study is to understand human factors psychology that includes an understanding of PCOS patients' behaviours and mindset during the entire roller-coaster of PCOS lifestyle. This study may provide a platform to design a solution that helps PCOS patients to overcome infertility issues in the future.

2 Method

Secondary research was carried out to understand PCOS. As the authors are from a design background and not from a clinical background, this secondary research gave an overall idea about the study on PCOS.

It is important to talk to all the stakeholders related to this study. Three gynaecologists were interviewed multiple times to understand the issues related to infertility,

PCOS, the relation between infertility and PCOS, and other risk factors by PCOS on the lifestyle of the patients. A semi-structured questionnaire was first formed for the interview. The three gynaecologists were from different regions to facilitate us with diverse first-hand knowledge. One from the USA, one from the urban area in India, and the third one from rural India.

After interviewing a gynaecologist, it is very much important to talk to patients suffering from PCOS to understand their issues with the insight acquired. The survey form was circulated over social media to get a response pan India. Forty-three participants participated in the survey. Out of 43, 18 were suffering from PCOS. In the survey, it was mentioned that the information of patients will be secured and would not be shared with anyone. The questionnaire of the survey form was formed keeping in mind the quantitative responses. All the questions were in objective format to analyze with the help of charts.

For a qualitative study on their quality of life, four interviews were taken. Three interviews were taken by telephonically and one was taken on a video call. Participants' age range was between 21 and 25 years. Before these semi-structured interviews, a questionnaire was formed and each interview took 25–40 min to complete. Questionnaire for a qualitative study focused on parameters such as symptoms, relation with diabetes, the stress of work or study, type of medicine, diet, exercise, sincerity towards doctor's suggestion, the reason for neglecting doctor's advice, etc. Along with the research, analysis of data extraction was carried out simultaneously. Once the research was done, all the insights were mapped out on a white canvas to find out the patterns, patients' pain points, and patients' gain points. This analysis helped to generate the point of view and a problem statement to further work on the solution.

3 Results

As mentioned, three gynaecologists were interviewed multiple times to understand PCOS and its relation to other health issues. On the basis of the interviews conducted, the following insights were generated. To avoid the redundancy of insights, recurring interviews were scheduled with only three gynaecologists. They were from different centres based on population such as rural centres, urban centres, and metropolitan centres.

3.1 Relation of Hormones to Infertility

1. If stress increases due to any reason, the progesterone level in women's bodies decrease along with it. The doctor prescribes an injection for the same to conceive a child and suggests the patient lower the stress to increase progesterone.

2. High insulin level also has a direct connection with infertility. The doctor prescribes an insulin-resistant diet to lower the insulin level.
3. Before getting pregnant a patient needs to check thyroxine level. Many times it is being neglected by some professionals. From blood tests, it can be easily monitored to avoid any further complications.
4. Prolactin is also an important hormone neglected by many professionals. It is high in only pregnant women to save them from cancer. If it is already high and one is trying to conceive a child from intercourse, the results would not be encouraging. The reason being, prolactin covers the follicles and restricts the egg to come out of it.

3.2 Insights from the Gynaecologists

Dr. Urvi Mehta (Gynaecologist at Gandhinagar, Gujarat, urban centre in India): "We recommend parents of PCOS patients not to wait for their marriage. They should get married as early as possible between 26 and 30 age. If they cross the age of 30, then conceiving pregnancy would be so hard for them."

Dr. Nirmal Solanki (Gynaecologist at Dhrangadhra, rural centre in India): "Divya (Name changed) had PCOS. She was unable to get pregnant for ten years. I never suggested she go for Intrauterine Insemination (IUI), as during treatment in IUI, the hormonal injection could lead to Ovarian Hyperstimulation Syndrome (OHSS) and that can cause more problems."

Dr. Katherine Lawrence (Gynaecologist from New York): "Monitoring hormones can help the patients and doctors to decide on medicines. All hormonal imbalances could be measured through blood tests. Every 14 days cycles are changing. At that time the ratio of FSH: LH can give accurate results by which gynaecologists can prescribe medicine and hormonal injection. For PCOS patients, this test would not give accurate results."

3.3 Quantitative Analysis on PCOS Patients

Out of 43 participants that participated in this survey, 18 were suffering from PCOS. Figure 1 shows the crucial quantitative analysis, which gives key points in this research.

Figure 1a indicates that half of the participants were diagnosed with PCOS at the age of 16–20. Previous studies also show that mostly in adolescent age, girls are diagnosed with the same.

Figure 1b indicates that late periods and facial hair growth are two common symptoms found in participants. While talking to them, many participants waited for

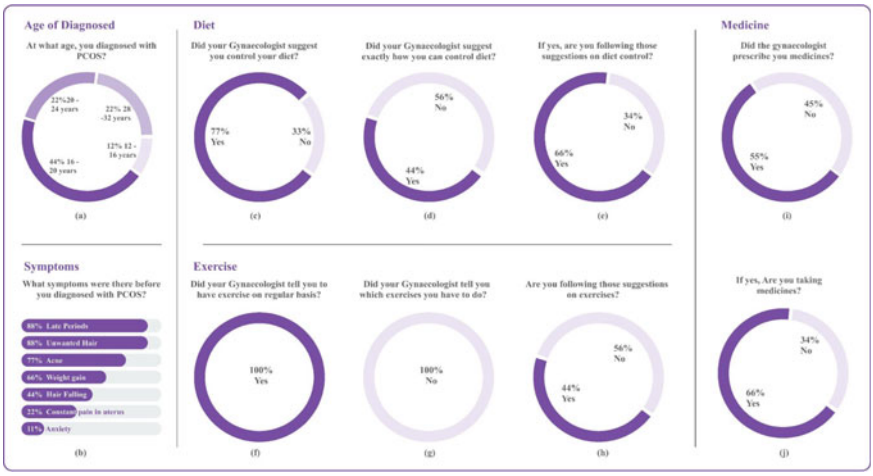

Fig. 1 Result of quantitative research

their period cycle to be normal and did not visit the gynaecologist early. It is advised that early diagnosis can improve the condition more effectively.

Figure 1c, d indicate that almost all gynaecologists are suggesting diet control to PCOS patients but half of them never suggested how one can control diet. PCOS patients do not have proper guidance on controlling diet. No such advice was provided on what to eat and what not to?

Figure 1e indicates that more than half of the participants are following advice on diet control. On discussion, it was observed that they are still not sure what to eat and what not to. They are relying on the internet for that or they just blindly assume what they can eat and what not.

Figure 1f, g indicate that all the participants received advice from gynaecologists to exercise, but none of the gynaecologists told them the type of exercise. It seems like gynaecologists are advising on exercise or yoga but are not referring to particular exercises for PCOS even though there are particular exercises for this condition.

Figure 1h indicates that more than half of the participants can not follow the suggestion of doing exercises.

Figure 1i indicates that more than half of the gynaecologists have given medicine for this condition even though there are more side effects than good effects.

Figure 1j indicates that one-third of participants are not taking medicine for this condition because of side effects.

3.4 Qualitative Analysis on PCOS Patients

Four participants have shown interest in a detailed conversation about PCOS. Three interviews were taken by a phone call and one was taken by a video call. Participants' age was between 21 and 25 years. Before these semi-structured interviews, a questionnaire was formed. Each interview took 25–40 min. All the insights were clusterized as mentioned below.

Time of Diagnosed

I was having irregular periods for 1 year. I did not give so much attention to this but after 1 year I was bleeding heavily. My mother then insisted that I should visit a gynaecologist for a check-up. At that time I was diagnosed with PCOS. (Amitha, 25)

When I was in 10 standard, my menstruation cycle became irregular, acne started coming on my face. My elder sister was also diagnosed with PCOS that is why I visited the gynaecologist after 7 to 8 months. (Pooja, 23)

I was diagnosed in January 2021. In July, my cycle got completed and the next cycle ended in December. It means there was a gap of 5 months. I visited a gynaecologist just after that. (Ikshita, 25)

When I was 19 years old, I was diagnosed with PCOS. At that time I gained so much weight and my period was also very irregular. After 3 cycles of irregular periods, I visited a gynaecologist and got to know about PCOS. (Mrinalini, 24).

Medication

After diagnosis, I started taking medicine. When I was in 10th standard, I stopped going to school while having periods because of heavy cramps and bleeding. Even while having allopathy medicine, many times I have fainted in school. (Amitha, 25)

I started taking medicine prescribed by a Gynaecologist. I must say that they are for temporary benefits, not for long-term relief. While taking those medicines, I had regular periods before but once I stopped it, it came directly after six months. (Pooja, 23)

I never went for allopathy after being diagnosed with PCOS. I went to homoeopathy. I have good relations with my homoeopathy doctor because she is from my family background. My doctor is not only focusing on medicine. She also tells me to focus on mental health, diet, and exercise. She calls me every weekend just to know the status of stress on weekdays. I feel so relieved after talking to her. (Ikshita, 25)

Family Background

Clinically no one was diagnosed with PCOS from my family but we have diabetes in heredity. (Amitha, 25)

My mother was having PCOS, not clinically but practically she had. My father has diabetes. My elder sister is also having PCOS. I knew that shortly, I would be diagnosed with PCOS. My sister is married and having a problem conceiving a child too. She recently did IUI but she delivered the baby very early and the baby could not survive more than 2 months. PCOS does not only give you a syndrome but also post or pre-traumatic stress. (Pooja, 23)

My mom was not clinically diagnosed with PCOS but was suffering from the same symptoms. My grandmother has type 2 diabetes. (Ikshita, 25)

My mom had PCOS. My sister is having too. (Mrinalini, 24)

Diet and Exercise

Gynaecologist suggested that I have sound sleep, diet control, exercise, and routine life. I am not finding time due to a busy schedule for all of this. (Pooja, 23)

As I am taking homoeopathy, the doctor told me to be careful about sugar and salt consumption. I can't take artificial sugar. My doctor encouraged me to have lifestyle changes instead of having medicine. Even though she suggested that I focus on diet and exercise, I can't follow that suggestion due to my schedule. (Ikshita, 25).

My homoeopathy doctor suggested that I should not take any hormonal tablet. She didn't suggest any exercise. She mentioned the gym for cardio, not for weight lifting. She suggested I take food every two hours instead of having a complete meal at a time. She suggested that I walk for 5 min after a few hours of work on a desk. Before I joined masters I used to go for yoga but now I am not finding time and place to go for yoga. (Mrinalini, 24).

Lifestyle

Neither my mom nor I had an idea about PCOS when I was diagnosed with it. I Used to eat a lot of chicken regularly. I used to skip meals and sleep during my graduation due to lots of submissions and jury panels. I was so immature in my bachelor's and I never took it seriously. I can't even take medicine while I am in the hostel because of side effects. (Amitha, 25)

I am doing freelancing work along with a full-time job. The work culture at the job is so toxic. I guess due to this stress I was diagnosed with PCOS. Due to these busy schedules, I can't find time to work on diet and exercise. It is so hard to manage my time. I think I need a planner. (Ikshita, 25)

I think sudden change can cause PCOS. A sudden and stressful change to be more precise! In my graduation time, I was diagnosed with PCOS. I went to a hostel for the first time during my graduation. Environment change, emotional affect and diet change could be the three most important reasons behind my PCOS. My performance in the second semester of my bachelors was also not so good. Due to all this, I was under so much stress. (Mrinalini, 24)

Frustration

It is kind of a hidden taboo so you can not even talk to your relatives about it, otherwise they will start judging and might create problems in future for the marriage because of some myth. (Amitha, 25)

Even though I am a medical student I lost hope because I can't do all of this because of time and sincerity as well. One needs so much motivation to follow all of this. (Pooja, 23)

I am foody. I love to eat all the tasty dishes and junk food outside. I really can't control my diet due to this. I know I need to control but still, I end up eating once a week. It was 2–3 times a week before I was diagnosed with PCOS (Ikshita, 25)

3.5 Summary

During convergence of the insights, it was noticed that the insights of qualitative analysis are interrelated to each other. As an example, if a PCOS patient has diabetes in the family background, and she is taking stress, it increases her chance to be diagnosed with PCOS in near future. Though all parameters are interrelated, "lifestyle" and "family background" seem to be a major role here in PCOS.

4 Discussions

The most common symptoms for PCOS are irregular periods. All the participants mentioned that they had visited a gynaecologist after having irregular periods. They went to the gynaecologist after 8–12 months of irregular periods, not immediately after having irregular periods. 3 out of 4 participants were in school at the time of diagnosis. It becomes really hard to manage those things at that age. In today's world due to competition, even the girls equally have the pressure of career-building. All of the participants were not aware of PCOS when they were diagnosed with it. It becomes so critical for them to be emotionally and physically strong.

Talking about medicine, all the participants knew that there are many side effects of allopathic medicines for PCOS. Tablets help them to keep their period regular but only when they are having that. Once they stop, the condition worsens than before. Still, after having medicine, PCOS can not be cured. Diet and exercise are the only two things suggested by doctors to manage PCOS.

Due to busy routines and lifestyles in this competitive world, patients are not finding time to manage diet and exercise for their betterment. The issue is not only time-constrained but the patients do not even have proper guidance about it. Further, if we discuss the lifestyle, the stressful environment in schools/colleges or offices makes it worse for them. They can not find time for exercise/yoga to manage PCOS.

While talking to participants, it was noticed that they have someone with diabetes in their family background. The previous study also showed that PCOS patients are more prone to be diagnosed with diabetes in the future. Even in one of the interviews, we noticed that the participant's elder sister (having PCOS) was diagnosed with type 2 diabetes at the age of 32. Insulin plays a major role for PCOS patients to control their condition. One of the gynaecologists, Dr Urvi Mehta also believes that continuous insulin monitoring and regulation can help PCOS/PCO patients to manage their condition.

PCOS is not considered normal by an Indian family and has a hidden taboo. Those who have been diagnosed with PCOS can not talk about this with their relatives because of their judgmental attitudes, as in the future, they might be judged based on infertility, which may cause a problem in their marriage.

Thus, these problems faced by PCOS patients open up many opportunities to work. There could be multiple solutions for each problem. The study of users would help to understand problems in detail.

Here are some of the possible solutions.

1. As discussed, there is a lack of awareness in new patients. Awareness in society is also very much needed. Spreading awareness through campaigns or NGOs or social media can help patients to talk about their problems/concerns.
2. The patients need support in this condition. A medium that can help connect PCOS patients with some support system can help a lot.
3. The patients need mental support to reduce the stress in their daily life as stress plays a major role here.

4. As patients are more prone to diabetes, preventive diabetes care should be there. Controlling glucose levels not only helps prevent diabetes but also helps to manage PCOS.
5. Once you are diagnosed with PCOS, you are not required to be medically examined with ultrasonic. It is required during their visit only. After that patients may not be required for regular visits. However, the patients need advice both from gynaecologists and psychologists at the same time. It is not only about organs but also controlling your pituitary gland in the brain to keep your hormones balanced. No one considers visiting a psychologist. The solution should include a service where the patient can talk to a gynaecologist and psychologist at the same time at a bare minimum cost.
6. By glucose monitoring, one can manage PCOS for sure. From monitoring glucose they can have an idea about their diet plan. LH monitoring could also play a major role for a gynaecologist to decide upon the next plan to manage PCOS.
7. Patients are not finding even 20 min to exercise. It is not because they are so busy but because they can not manage their time very efficiently. They need a planner to manage those things. It could be a digital or a physical one.

This study is limited to the first diamond of the design thinking process that is the research on PCOS patients' behaviour and mindset on various parameters. There could be a lot of research scopes while deriving solutions to the problem identified in this study. As an example, while ideating on the problem of irregular diet, there could be a lot of user research needed with a nutritionist to decide upon the best option. For every solution, there is a need for extensive research.

5 Conclusions

This study helps us to understand PCOS patients' challenges in managing the condition. The quantitative analysis gave an idea of the problems faced by patients in general. The qualitative analysis in this study helps to understand patients' mindsets and behaviour while managing PCOS. Six primary factors are covered in qualitative analysis that gives us major insights into their lifestyle for managing the condition. Both quantitative and qualitative analysis opens up many opportunities for the design intervention in a domain that is critical but often neglected due to unawareness. This research on PCOS patients' mindset and behaviour towards managing PCOS may become an important resource while ideating on the solution to the identified problems.

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Visual Analysis of Narratives in Naamghars of Assam

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Abstract Visual narratives are the most important aspects and culture threads which bind together the people and their belief in Naamghars and Satras of Assam, It has been brought into existence in Assam by the Vaisnavite Saint Srimanta Shankardeva between twelfth and fifteenth century AD. Naamghars are the vernacular structures where communities come together to reside the name of God as well as its the central meeting point for the communities to preserve the culture of Assam (Mahanta in The Sankaradeva movement its cultural horizons, 1st ed. Purbanchal Prakashan, Guwahati, 2007). There are major design elements which narrates and depicts the stories on the walls, pillars, jali's and other corners of the Naamghars with intricate traditional craftsmanship rooted with semantic and metaphorical meaning. In this study the researcher has found that the design elements were planned using elements related to dashavatar, specifically Vishnu, which is associated with flowers like lotus. Creators of Naamghar have incorporated 'nirmali' flowers and lotus to build the connection with devotees in the space of Satra and Naamghar. Extensive field survey has been done with 263 respondents to derive on the list of narratives and design elements which retains the identity of Naamghars. Data repository has been created with the help of primary and secondary research and its segregation has been done in rural, semi-urban and urban settings of Naamghars to analyze the major narratives which constructively retains the designs of old age traditions in Naamghars of Assam.

Keywords Naamghar · Social-cultural institution · South-East Asian cities · Design elements · Multidisciplinary culture · Vernacular architecture

1 Introduction

Naamghars were introduced in Assam by the Vaisnavite Saint Srimanta Shankardeva (1449–1568) between fifteenth and sixteenth century AD. Shankardeva was a great

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social reformer. The "Naamghar" is been divided into two sections "Naam" meaning "Name" and "Ghar" meaning "House"; is a place of congregational worship and other activities associated with the Ekasarana religion of Assamese society [5, 7]. Naamghar is associated with a whole initial movement which served as a building block of Assamese society also its a central place for worship as well as community meeting space to discuss societal issues [9]. Presence of narratives all over the space plays an important role which is visible in Naamghars of Assam. It works like a visual reminder for the visitors towards the main purpose with beliefs attached towards space and society. The stories are about Krishna, dashavatara and its incarnations etc. Naamghars are the nucleus of any Satra in Assam which has been first established by Srimata Shankardeva to bring people together towards oneness [6]. It's a community place which brings many kinds of ethinic groups together under one roof. The community space has different sections devoted to various activities. In this study the researcher has understood and shown the narratives of Dashavatar on the outer walls, doors as well as on Manikut of Naamghar (Fig. 2). It has also been identified, observed, studied by coding each element which is present in the Naamghar space. Further it has been found that flowers like lotus, presence of bhakats and shankha have been extensively used at different positions (Fig. 18).

In day to day social life scenarios design plays a very significant role as it's considered to be a creative activity. There are many simple to complex as well as large to small spaces created by incorporating creative human urges where design plays a mutual relationship to bridge the gap between societal setup and changes also where architecture of religious places like Naamghars have gone under design transformation from the historical point of view at different periods of time [3]. This particular study highlights the relation between design elements of Naamghars over the period of time. This research explores the levels of cultural re-construction of design elements in narratives, which also brings together people of Assam from different facets of life. The aim of this research is to understand various kinds of narratives, which have been portrayed in Naamghars of Assam in the objective also to study the variations in them.

1.1 Methodology

The study involves the social expression and inter relation between the Naamghars and society. The methodology involved in unfolding the meaning through denotation and annotation was carried out with qualitative analysis. The structured analysis through categorization theory of design elements was done and further through taxonomic structured segregation, data collection has been performed [2]. Each and every element which came out of the study was properly coded and divided into three levels like Superordinate level, Basic level and Subordinate level to understand the layers of meaning attached with Assamese Naamghars. It has been done to unfold the functional meaning of each and every element. The 'Exterior' elements of the main gate and outer gate were studied and the 'Interior' elements of hall and manikut

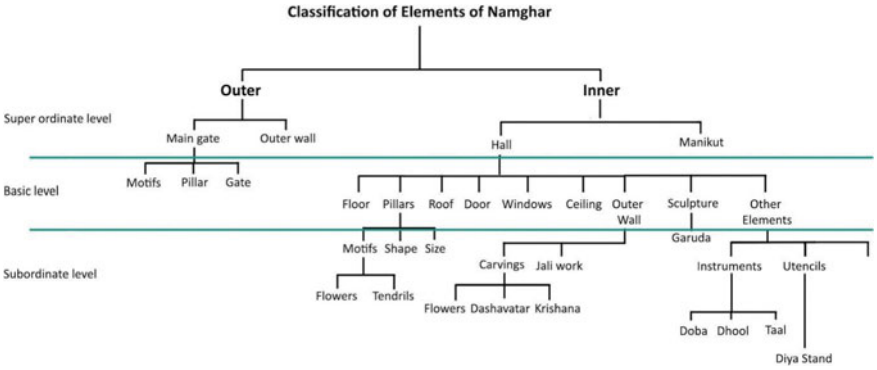

Fig. 1 Categorization of elements in Naamghar (Adopted from Athavankar, Uday A. 1989) ("Categorization Natural Language and Design")

Fig. 2 Depiction of stories of Krishna on the outer walls of Kirtan Ghar

were studied as well as shape, signs, motifs, carvings, jali work etc. (Fig. 1) has been researched and detailed out [1]. Further with the help of reverse card sorting technique typicality analysis has been done to observe the respondents view points [8].

1.2 Data Collection Method

Categorization theory has been used to segregate and analyze various narratives in Naamghars of Assam. Analyzing elements in relation to Naamghar has covered the series of design elements that goes into making these changes. Some of the elements which have been discussed in this paper in relation to visual narratives are Jali work, dashavatara, flowers, petals, animals and plants which adds a value in the identity of any Naamghar of Assam. With this Typical and A-Typical analysis has also been done to understand the variations and acceptance of those variations within the society. The series has been explained below.

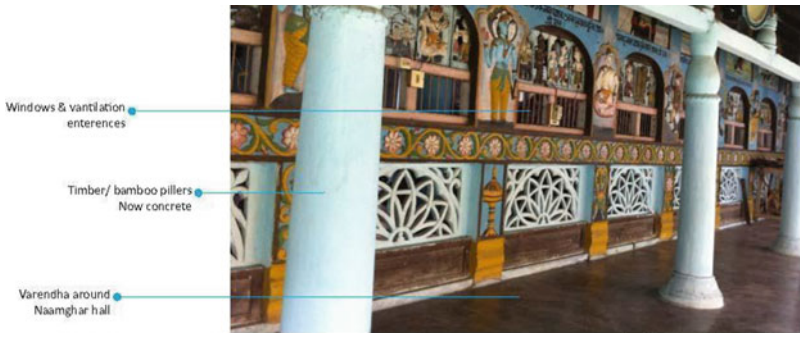

Fig. 3 Ramdiyar Naamghar; Sualkuchi Village

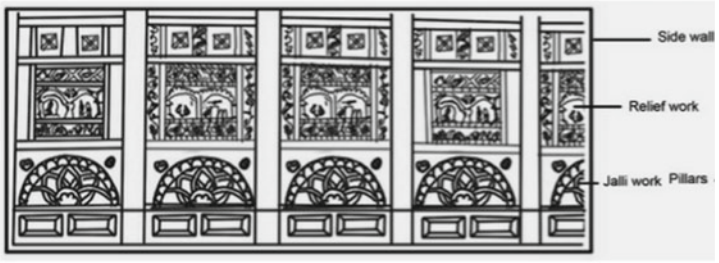

Fig. 4 Narratives of Krishna carvings on the walls of Naamghar

1.3 Naamghar Walls Depicting Narratives

Presence of dashavatar with narratives of krishna has been found on the walls of Naamghar. Specific colours, size and materials have been used to retain the traditional identity of the space as well as identity in terms of visual hierarchy. It has been said that the size of the narratives on the walls of Naamghar [4] is equivalent to 'vrindavani vastra' where again stories related to Krishna have been depicted (Figs. 2, 3 and 4).

1.4 Presence of Narratives on Main Door and Main Gate of Naamghrs

1.4.1 Main Gate

Presence of bhakats and xorai as sculptures on the main gate to welcome devotees inside the Naamghars has been noticed. It has also been noticed in the rural and urban setting Naamghars (Fig. 5). Height of the gate has also been observed as over the period of time and space there's change of size and height has happened.

Fig. 5 Symbolic representation on the main entrance gate of Naamghar

Fig. 6 Comparison of main door of Naamghars in Rural semi-urban and Urban area

This also affected the viewpoint of the respondents in terms of identifying the right visual identity of the Naamghars. The visual ergonomics of gates were identified with various elements and segregated to further show the cards to the respondents for typical design elements identification.

1.4.2 Main Door

Dashavatar on Main Door: It's also been called 'Saptam dwar' meaning first entry door and the most recognizable narratives on the Main Door are all incarnations of vishnu. There are a total nine avatars which have been represented on the main door like fish, narsimha, buddha, kalki etc. which again reminds every bhakat about the goodness done on the earth by dashavatar and vishnu (Figs. 6, 7, 8 and 9).

1.4.3 Vakhuntha (Unnat Sajja/Vakhuntha Dhamm)

Vishnu is considered to be the supreme of all as well as a preserver. It's present in the Naamghar at the top of the main door where it's been represented in the position of main dham. It shares the story of Vishnu puran and says Vishnu is the supreme of all and all others are its avatars. In Hindu iconography, the colour of Vishnu is depicted

Fig. 7 Variety of doors in Naamaghar

Fig. 8 Cement, wooden and metal relief work in Naamghar

Fig. 9 Wood carving on the Naamghar door

Fig. 10 Unnat Sajja relief in the doors of Naamghar

Fig. 11 Narratives representation on wooden pillars in Naamghar

as dark and blue complexion with four arms in which he holds a lotus in lower left hand (padma) and a mace in lower right hand (kaumodaki) and a conch in upper left hand (Panchajaya shankha) also discus (Sudarshana Chakra). Traditionally Vishnu is sitting on the coiled serpent shesha with Lakshmi as he "dreams the universe into reality" (Fig. 10).

1.4.4 Jaya Vijay

In the pillar carvings (Fig. 11) one can see the two gatekeepers of Vishnu named Jaya and Vijay, who protected the main entry gates known as Vaikuntha meaning place of eternal bliss. It has been said that once Vishnu was resting and Kumaras wanted to meet Visnu and on this Jaya Vijay has stopped them at the gate saying it's not possible to meet Vishnu as he is resting. On this Kumaras replied that it's impossible as Vishnu is available anytime for his devotees and on this he cursed Jaya Vijay but suddenly Vishnu appeared and asked Kumaras to undo the curse but the curse was not reversible. Instead, he said that either Jaya Vijay can take seven births on Earth as a devotee of Vishnu or take three births as an enemy of him. As Jaya and Vijay

were totally devoted to Vishnu so they were not able to take the pain to stay away and choose to take the birth as enemies as three years were lesser than staying away for seven years.

1.4.5 Motifs

It's been associated with elements of nature especially flowers and plants like "Rangiyal and Ashoka flower" which is associated as a symbol with Madhavdeva, who was Srimanta Shankardev's disciple. Motifs and its position, placement and size contribute in an extensive manner to retain the design identity of any Naamghar of Assam (Fig. 12).

(i) **Jali and Forms in Assamese Naamghar:**

Jali's are an important part of Satras and Naamghars and it's been integrated in many forms at several places. It is extensively used towards the varandha side so that devotees can hear and participate in the Naam Kirtan as it happens in Kirtanghar. Its other purpose is to maintain the ventilation within the Naamghar. The size and height of the jali's differ according to its positioning within the organization. Researchers have also found that incorporation of lotus which is associated with Vishnu has extensively been used in the jali's as a design element (Fig. 13). The other purpose to use lotus, nirmali and ashoka flower as an important element in jali is to build the emotional connect as well as a reminder towards association of devotees with spaces of Naamghar. Researchers have explored the forms on the basis of parameters

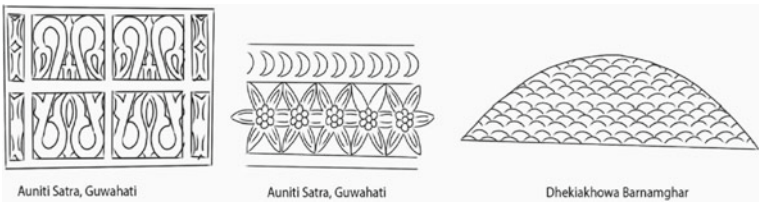

Fig. 12 Rural Naamghar: Jali work pattern

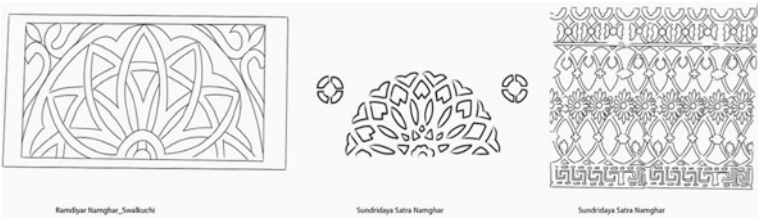

Fig. 13 Semi Urban Naamghar Jali patterns having influence of traditional lotus flowers

Fig. 14 Urban Naamghar Jali patterns having influence of Dashavatar

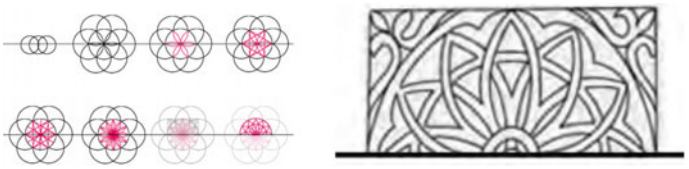

Fig. 15 Jali work of Ramdiyar Naamghar is being analyzed, which is in semi-urban settings unfolding the geometric shapes and patterns

like population in selected locations at rural, semi-urban and urban settings (Figs. 14 and 15).

(ii) **Naamghar Jali with flowers and tendrils:**

(iii) **Flower variation analysis:**

The use of lotus patterns in the Jali work has been analysed and the researcher has tried to understand the use of symmetrical patterns as the artisans have developed the lotus at various positions. The equal division of petals was observed as it has been replicated at various places and kept in mind as the pattern grows in different directions. The symmetry is also centrally divided from the bud of the lotus (Fig. 16). Further researchers have analysed the different styles of lotuses at various Naamghars (Fig. 17). It has been observed that form has been modified but the concept of lotus remains the same especially in semi-urban and urban Naamghar settings. Hence, it can be identified in various formats and sizes as the approach of developing is the same. Similarly its been done with nirmali and ashoka flowers.

The variations of Ashoka and Lotus flower have been observed and recorded, which has been shown in Fig. 18. The researcher has identified the flower elements in 26 Naamghars and categorized and coded them in a matrix on the basis of size and form to observe the visual ergonomics indicating various dimensions (Fig. 18). It has been analyzed that three varieties of leaves, which are associated with Shankardeva

Fig. 16 Analysis of lotus and flower associated with Naamghar

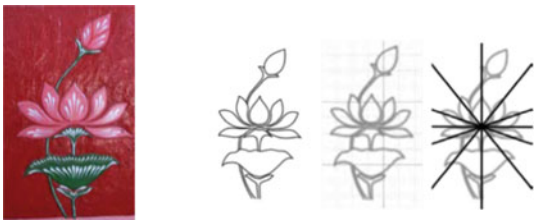

Fig. 17 Analysis of flower associated with Naamghar

Fig. 18 Geometrical variations analysis of flower **a** Jali work in Naamghar and **b** design detailing of Ramdiyar Naamghar Sualkuchi in Semi Urban setting, **c** lotus flower form in Urban setting at Big Bazaar Naamghar, **d** lotus flower forms in Rural, Semi Urban and Urban Naamghars, **e** form analysis of Ashoka flower at Srimanta Shankardeva Kala Kriti Kendra Naamghar and Naamghar path, **f** matrix depicting natural elements and their designs associated with Naamghar

and Madhavdeva have been used in the Naamghars walls and pillars. Another observation is about the use of four to eight numbers of petals, which is varying in different locations. Colour plays a very significant role as it is almost similar in every location and can be recognized in a very clear manner.

1.4.6 Study of Krishna in Naamghar

The importance of Krishna in the Naamghar of Assam has always played a central role in rural, semi-urban and urban settings as its one of the Dashavatar. The researcher has done the visual documentation of Krishna in various forms. It has been observed that the size is continually changing in terms of visual ergonomics but its presence on the main gate has been retained to tell the devotees about its association with the vaishnav culture and to build the connection with the devotees in terms of sharing

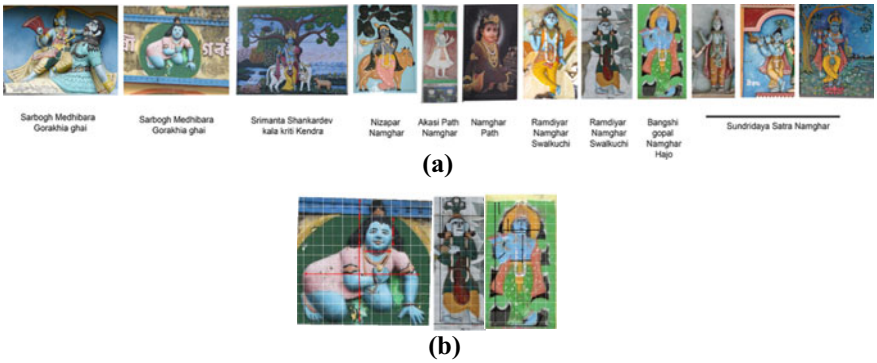

Fig. 19 **a** Krishna idol variations in Naamghars, **b** size variations of Krishna idol

the stories of lord Krishna. The various narratives of Krishna leela have been shown sometimes in scenes of Kalia daman and sometimes in the stories depicting good over evil. Some of these stories were shown in the forms of carvings and sculptures on the walls of Naamghar as well as in the central part of the pond, which is also part of the Satra and Naamghar (Fig. 19a, b).

As observed by the researcher in the set of pictorial images, the version of child Krishna is being used in the rural Naamghars in the form of sculpture and carvings especially on the main gate and in the form of jali works on the side walls. The other observation is about the presence of Krishna's idol in adult form as it has been used in the urban Naamghars in the form of posters and calendars (Fig. 19a, b). One of the Naamghar which is in the city and it's in an urban setting has sculptures of Krishna idol on the outside wall showcasing adult Krishna with flute under a large tree to give an indication of presence of Naamghar as well as showing harmony in nature.

1.4.7 Dashavatar Elements on Pillars

The pillars were observed in Naamghars in rural settings, where the use of a separate pedestal has not been made; rather the capital is adorned with a pot shaped hat, over Bhakat's head. The height of the pillars were also observed for comparison. The significance of bhakat on this pillar is quite important in Vaishnava sect, as Naamghar is totally based on it. The researcher has compared the visual ergonomics of the pillar size in semi urban Naamghars, in which one of the incidences of Krishna has been depicted where his father Vasudeva was carrying him as he was a baby through the sea. This was found to be the most distinguished piller only available in rural Naamghar and adorned by many intricate carvings having large pedestal but the size of the pillar is quite short as we compare it with other pillars. The pillars in urban Naamghars are pentagonal in shape without any decoration and no clear distinction of abaqus, annulus and also fluting are present. This is a clear indication that with the changing of time and space, loss of design elements has happened. The reason

(a) (b)

Fig. 20 **a** Hajo Naamghar: the shaft of a wooden pillar is carved with bhakat decoration. **b** Ramdiyar Naamghar: horizontal bands used as decoration

behind this can be lack of skilled craftsmen and artisans as well as non availability of the sufficient funds and also non preservation of various design elements associated with Naamghars were made (Fig. 20).

2 Setting

2.1 Group Discussion

With 263 number of respondents and 26 Naamghars as sample size, focus group discussions were made to analyse the results by dividing them into two sets of groups. Categorized pictorial images were shown to them of various sections of Naamghar like doors, pillars, manikut, narratives etc. and viewpoints were noted down as well as with typicality analysis data have been segregated. While segregating the cards, respondents were allowed to discuss with each other to confirm the traditional aspects of elements (Fig. 21). Respondents from various communities were involved like

Fig. 21 Focus group discussions with stakeholders

Satradhikari, visitors, nearby shop owners, bhakats etc. to incorporate their observation and experience. Both literate as well as illiterate respondents were involved in the card sorting process. The researcher has noted down the responses, observations as well as taken field notes while conducting the interviews.

3 Summary and Conclusion

Vishnu is the most famous form of Rama and Krishna. Vishnu's wife Lakhmi was the Hindu goddess of luck and fortune. Vishnu is usually shown with light blue skin and four arms. He holds a lotus, mace (gada), conch (shankha) and Sudarshan chakra in each of four hands. Presence of a peacock on the top of the door is a symbol of Sri Krishna. The whole main door should give the aura of Vishnu's stories. According to the respondents the traditional influence is required on the main door.

In-depth study to analyse the variations in visual design and architectural elements of Naamghar has been done for the outer gate, main gate, pillars, central prayer hall and Manikut in all the three rural, semi-urban and urban Naamghars of Assam. The striking difference has been seen in the relief work also the ornamentation work, which has been done on the walls and pillars of Naamghars in the selected three categories. Over the period of time in urban Naamghars the decorations have been reduced and almost became nil due to urbanization. The researcher has analysed the shape and form of the outer gate which has been changed from polylobed in rural Naamghars and taken a simple form of hexagonal shape in urban Naamghars. The relief of Krishna lila (narratives of Krishna) vanished from the present urban Naamghars and the reason behind this might be due to the availability of Bhagvad in digital media and presence of calendars, printed and other digital material in an easier manner. In the outer gate of Naamghar presence of main elements like flying singha (flying lion), horai and other Vaisnava elements also floral carvings, which were the major part of rural and semi urban Naamghars are now missing in urban scenario and it has been changed to more plain and simpler design where decorations are almost vanished. Similarly, the relief and complex iconographic and floral carvings which depict Vaisnava elements on the pillars of rural and semi urban Naamghars are no longer available on pillars of urban Naamghars and it has been changed to a totally much simpler plain round shaped form. In terms of the material usage the durability has been increased over the period of time. For example, in rural scenario mud floors were used but now it's been changed to marble flooring in urban Naamghars also the use of glass has increased in urban scenario for the doors and windows replacing wood, thatch and tin (mostly used in roof and windows). In case of pillars, carvings which were a major part of the top portion (capital) and pedestal (bottom) are missing and no more decorations are used. The relief work on the outer walls of Naamghars has played an important role as it depicts various narratives of Vaisnava sect also inviting bhakats towards the Naamghar but in urban scenarios the design elements are just left on the main door and it's vanished from outer walls, doors and pillar of the Naamghar.

In the urban scenario more energy efficient structures were developed from the architectural design perspective. Also as observed in rural, semi urban and urban Naamghars, Manikut's form, elements, shape and colour seems to preserve its design identity in the most efficient manner. Overall, modernization has taken over focusing on the security issues as compared to retaining the identity of iconographic design, relief and decoration work in the design of architectural elements of Naamghars in urban locations.

4 Conclusions

As mentioned above the complexity of the elements involved in the study were deciphered using a number of techniques viz. questionnaire, data characterization, semantic, denotation, connotation and card sorting analysis. The following techniques were crucial in unfolding the meaning of each and every element related to social, cultural and design aspects. Methodology played an important role and appropriate examples have been selected for the related illustrations in each and every case. The researcher has found that various distinctive differences in interior and exterior have happened over the period of time in Naamghars of Assam. The changes in physical forms of pillars, ceilings, main prayer hall, jalis etc. had happened and in exteriors of Naamghar like presence of narratives, illustrative use of animals, birds as guards of the gate has happened. The significance of these symbolic elements are very important and integrated with the life of people in Assam extensively rooted in their culture. There are various layers of meaning associated with each and every element and it has been segregated by adapting the semiotic approach to unfold the meaning and values associated with Naamghars.

This also provides an in-depth understanding of various design dimensions, which has been adapted and survived till present time. The real example is the presence of Dashavatar, Jay Vijay, various flowers and animals etc. as narratives to share about the ergonomical visual identity of the Naamghars in various scales and positions as a reminder of stories associated with Krishna. A systematic data analysis by adapting the card sorting analysis by Athavankar has been done and sequential visual cards have been created, coded and on the basis of typicality rating analysis has been done. The Connotation method seems fit to analyze the gathered data.

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Eye Tracking to Evaluate the Usability of User Interfaces

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Abstract User Interface is that part of the equipment with which the user communicates with the product. These user interfaces are the buttons, touchscreen, knobs etc. These should be designed in a manner that every user can use it efficiently. But in reality, the users are having a fear to use it. In the present study it was found that among all the equipment's respondents were having a fear to use the microwave oven because of it complicated user interfaces. While using the microwave oven the users are facing lot of problems which are related to buttons, knobs, switches, touch screen, etc. of user interface. 90% of the respondents stated that there are too many buttons in the interface and 100% reported that the buttons are a waste of space. 45% of the respondents reported that there is a bad contrast between the keys and the equipment same percent stated that the font size is not legible and 90% reported that the distance between the keys are not sufficient to operate it smoothly. Thus, the usability is dependent on text style, location, size, colour and visual information of the components in the user interface. When these attributes are used effectively users use the product without any problem. The need of the hour is to study the usability problems while using the products. In usability evaluation, today eye tracking methodology is mostly used which can be a guide to improvement in design of user interface.

Keywords User interfaces · Usability · Eye tracking

1 Introduction

In the past few years there have been tremendous growth rate in consumer electronic products [1]. These electronic products have made the work easier for many people as a result they have become an inevitable part of life. Our lives are woven in such a manner into a plethora of such electronic products that, it has made our lives more enjoyable and hassle free. In an increasingly technological landscape, manufacturers

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must continuously innovate new products in the market in order to remain competitive. In order to cater to all the users' needs, the manufacturers are adding more functionality to their products. As a result, new products with multiple functionalities are flooding the market. Studies reveal that the users are reluctant to use these products since they have a fear in their mind while using the user panels. The user panel is the part of a machine, product, or device with which a person interacts. Usually visual and tactile in nature, a user panel is what an individual uses to make a machine or product do what the person wants it to do. These panels are termed as User Interface (UI). Though the manufacturers' main intention is to make the task easier, but then by doing so, the cognitive load on the consumers are increasing when they use an interface with multiple functions. Imami et al. [2] reported that many new features and their user interfaces in the recent home appliances are renewed frequently. Though these new features allow the user to operate many things but people may still find difficulty and struggle to get used to these new interfaces. As new technologies penetrate the lives the users no longer know what functionality to expect from the appliances. User panels are governed by the attributes as the text style, location, size, colour and visual information of the components in the user interface. When these attributes are used effectively they guide the users in viewing the user interface smoothly in turn use the product without any problem. In such situation, the need of the hour is to develop usable and needed products by integrating product planning, designing and manufacturing. Indian consumer electronic market has been witnessing substantial growth in past few years. Electronic products help the daily activities of all the people saving time and alleviating the burden of fatigue. More functions are added to the electronic product as a result the appliances become more complex and have added more attention by the users. More features will decrease usability and increase consumer complaints. Keeping these points in view the study was conducted with the aim to evaluate the usability of user interface through eye tracking method and to test the preference of certain attributes of user interface.

2 Methodology

The present study was conducted in three Phases.

For the phase I Purposively cum random sampling method was adopted in order to select representative samples for the purpose of the study. A total of 200 respondents were selected. Only households possessing most of the consumer electronic products were included among the sampled households. This has perhaps resulted in excluding those families which do not possess most of the consumer electronic products.

In the phase II of the study, user workshop was organized to prepare the mock up models/stimuli based on the preference test Forty numbers of samples were selected randomly from total sampled respondents of 200 (i.e., 20% of 200).

In the phase III of the study usability study was done on 20 respondents by conducting eye tracking experiment.

Eye tracking refers to the careful measurement of the movement of the eyes, whilst the human is looking at a display. In the present study eye tracking experiment was carried out for usability study. The eye movement matrices that will be used in this study are:

1. Area of interest (AOI): is an automated tool that allows the researcher to divide the displayed stimulus into different regions of interest. The system then tracks participant's eye movement automatically to calculate gaze data through linking the eye gaze with the different areas on the displayed stimuli.
2. Time to first fixation: the amount of time that participant takes to look at AOI for the first time.
3. Total fixation duration: it indicates the duration of participants fixation within the specified AOI and the average fixation duration is an indicator of cognitive processing.
4. Fixation count: these measures how many times participants fixated on AOI.
5. Scan Path: is an ordered set of fixation points (depicted by circles) connected by saccades (depicted by lines).
6. Heat maps: it is used to represent the visual behaviour of participant's attention based on fixation count. Where the red spot represents the most fixated and the green and yellow represents the lower fixated.

Apparatus: The Tobii TX300 Eye Tracker, was used for eye tracking experiment. Its high precision and accuracy, robust tracking and compensation for large head movements extends the possibilities for human behavior by studying eye movements such as saccades and short fixations. It captures natural human behavior.

Stimuli were prepared and presented on the 24-in. LCD monitor. This monitor is controlled by a PC positioned in the same room. A total of twenty number of participants were selected. Each participant selected was tested one by one, seated approximately 70 cm from the monitor alone in a quiet and darkened room. No specific instructions related to the task was given to participants, except that they were required to watch the images appearing on the computer screen and to look freely without restrictions wherever they felt like. Keeping the interface constant and changing the colour contrast was carried out to see the most acceptable colour contrast. The calibration of eyes was done and then the respondents were allowed to see the screen. Scan Path and Hit ratio were used from which numerical encoding was done to come to a conclusion.

3 Results

The study was conducted on urban women of Jorhat Assam and there was almost an equal distribution of respondents belonged to age group 26–35 and 36–45 years of 31.5% and 30.5% respectively. It was seen that most of the respondents possessed all the electronic equipments but then they found problem in using some of the equipments like microwave oven, induction cook stoves etc. Based on the results

from the respondents this study identified that 90% of the users face problems with buttons in the interface, 75% face problem in following the instructions in touch screen. 90% stated about having problems with the keys, which are very close to each other. So, it is seen that the users face problems in the user interface of the microwave oven as depicted in Table 1.

From Table 1 it is seen that cent percent of the respondents reported that the buttons are a waste of space and are flat with no tactile differences. There is a bad contrast between the colour of keys and product as was reported by 45% of the respondents and same percent of the respondents reported that font size used in UI is not readable and also the symbols are not easily recognizable. 40% reported that display is having bad contrast. Keeping these problems in view paired preference test was done to test the preference of font size and colour contrast to incorporate in the design guidelines to make the user interface a user friendly one.

3.1 Preference for Visual Attribute of Font Size for User Interface

Fonts used in interface acts as the most important form of communication between the appliance and the user. The user can perform the action only when he/she can read the text written in the buttons properly. Proper font size and style are important attributes for the UI readability. In order to accommodate too many functions in the interface at times some of the manufacturers overlook the font size of the button. According to [3] the font size should be standardised and must be readable. So the paired preference test was conducted to find out the readable font size to be used in the buttons of the user interface.

The respondents participated in the workshop stated that they have difficulty in reading the buttons properly. The font style and size used are not readable. Paired preference test was performed by increasing one font size than the previous one from 4.5, 5.5, 6.5 and 7.5 and the respondent were instructed to indicate their preferences. While finding the font size, same font style i.e., Calibri for different font sizes was used. Results of paired preference test are presented in Table 2. From the obtained scores the font size of 7.5 points with black in white background ranked I, which was followed by 6.5 points font size with black in white background and by 7.5 font size with white in black background.

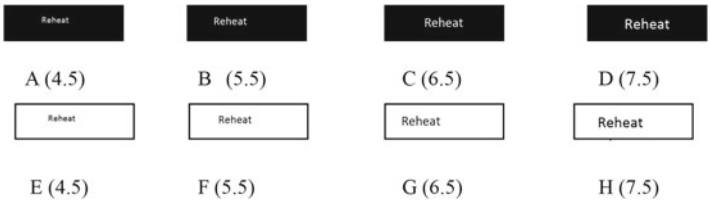
3.2 Preference for Visual Attributes of Colour Combination/Contrast

Colour combination/contrast is important factor to be considered for the visibility of the user interface. Nicolle [4] revealed that 70% contrast and font size of 4.7 mm ×

Table 1 Problems faced by the respondents while using user interface of microwave oven

Sl. No.	User interface	Problem statement	Frequency	Percentage
1	Buttons	There are too many buttons in the interface	180	90.00
		Buttons are not easily identifiable from each other	50	25.00
		Excessive force is to be used to operate a button	20	10.00
		Push button does not return to its out position after being pressed	100	50.00
		Most of the buttons are a waste of space	200	100.00
		Most of the buttons have no tactile difference	200	100.00
2	Touch screen	The instruction cannot be followed smoothly	150	75.00
3	Keypad	There is a bad contrast between the colour of keys and appliance	90	45.00
		Key size is not large enough	50	25.00
		Font size is not legible	90	45.00
		The distance between the keys are not sufficient to operate it smoothly	180	90.00
		Only lower case is used	150	75.00
		Font style is not clear	150	75.00
4	Use of colour for stop/start	Display is having bad contrast	80	40.00
		There is a glare on the display	50	25.00
5	Graphics	Proper graphics are not used in the keys to perform the respective function	50	25.00
6	Images	The text/image and background colour combination is low contrast	50	25.00
7	Symbols	Symbols are not accompanied by text	50	25.00
		Symbols are not easily recognisable	90	45.00

Table 2 Preference for font size for user interface



	A	B	C	D	E	F	G	H	Score	Rank
A		0	0	0	0	0	0	0	0	VIII
B	1		0	0	0	0	0	0	1	VII
C	1	1		0	1	1	0	0	4	IV
D	1	1	1		1	1	0	0	5	**III**
E	1	1	0	0		0	0	0	2	VI
F	1	1	0	0	1		0	0	3	V
G	1	1	1	1	1	1		0	6	**II**
H	1	1	1	1	1	1	1		7	**I**

height, 90% of people over age 65 are able to read it at least from 1 m. The highest possible contrast in a printed text ensures the user for the best readability of text. Usually, it is seen that dark letters on light background are mostly used but there is evidence that light letters on a dark background are more readable. To find out the readable colour combinations for user interface, different colour combinations were designed based on the colour combinations of mostly used brands of microwave ovens. After preliminary screening, four colour combinations were selected for paired preference tests. The selected contrasts were white font in black background, black font in white background, black font in maroon background black font in silver background (Table 3).

From the obtained scores, the combination B (Rank I) and A (Rank II) were found as best that is black font in white background and white font in black background. It is in accordance to the study by Hinum [5] that it is difficult to achieve high contrast colour combination other than the combination of black and white. This is the reason printed material is usually most readable in combination of black and white. So, while using colour combinations one should be very careful and use colour only for highlighting of regions or aesthetic reasons. Same font size i.e., 6.5 was used for all the selected colour combinations. The results of the paired preference test were experimentally tested by using eye tracking method for which stimuli was prepared to test the parameters.

Table 3 Paired preference test for colour combination/contrast

	A	B	C	D	Score	Rank
A		0	1	1	2	II
B	**1**		**1**	**1**	**3**	**I**
C	**0**	**0**		**0**		**IV**
D	0	0	1		1	III

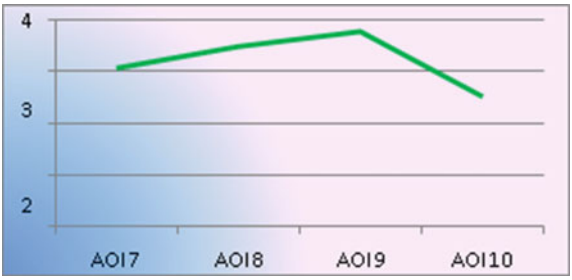


Fig. 1 Fixation count in different areas of interest (AOI 7–10)

3.3 Colour Contrast for User Interface Using Eye Tracking

To find out the colour contrast of buttons of User interface, four stimuli were selected. The stimuli were divided into area of interest denoted by AOI 7, AOI 8, AOI 9 and AOI 10 where AOI 7 represents Black font in white background, AOI 8 represent White font in grey back ground AOI 9 represents Black font in grey back ground AOI 10 represents White font in black background.

Fixation count A fixation is an instant where the eyes are relatively still and they can be measured by frequency and length of time looking at content.

During an encoding task, such as looking at a web page, a higher number of fixations indicate the need for processing time or greater difficulty identifying the target object [6]. Figure 1 indicates that graph is at the peak in AOI 9 followed by AOI 8 which indicates that the respondents have difficulty in identify the two stimulus in which the colour contrast used was black in grey (AOI 9) and white in grey (AOI 8) with which we can conclude that grey colour has more cognitive load and is not acceptable.

Average fixation Average Fixation indicates the number of fixation on an average is more for AOI 10 which means more number of respondents are looking at the AOI 10.

It indicates that AOI 10, where the stimulus is white font in black background was more preferred combination by the respondents. Hence, it can be concluded that for

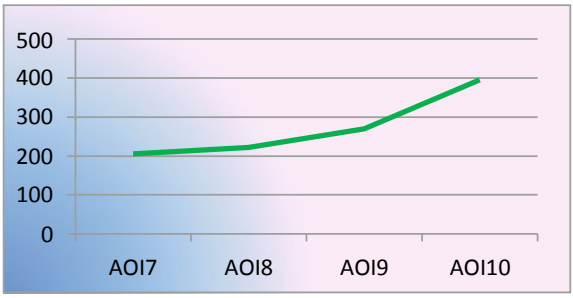


Fig. 2 Average fixation for different areas of interest (AOI 7–10)

information processing in the user interface, with white font in black background is easier than other combinations and the fixation count also shows the same trend and results in more cognitive load with grey background (Fig. 2) indicating that there is difficulty in this background.

From the results it can be concluded that more number of respondents are fixing their eyes in white in black background indicating that for information in the user interface white in black ground is more preferable as compared to other combinations. In a finding by Ux Movement [7] reported that for a paragraph reading one should avoid using white text on a dark background. When a user is forced to fix attention for a long time on the white text, the user's eye may strain. So, while scanning text by the user, white text on a dark background works well and is effective to grab user's attention. White makes the text brighter and distinct. Scanning doesn't take long visual fixation so it does not put any stress on the user's eyes.

Usability evaluation in the current context plays a very important role for improved task performance. Usability is a dormant concept and that can be measured indirectly [8]. Therefore, it is important that the researchers in this field should employ objective measures of usability in addition to the often-used subjective usability measures as this will enable correct replication of research studies and would help the further development of the definition of usability. Furthermore, it would advance developments in the design of user interfaces, as they still appear to puzzle users. That is, if there is independent evidence that a particular user interface design element is essential to improve usability, then this would help the user interface design practice, as this particular aspect would not necessarily need to be assessed again.

4 Discussion

From the above results it came into foreface that problems in microwave ovens were more pronounced. This may be because of having more of functions in microwave ovens. Microwave oven has added an innovative dimension differing from the traditional appliances used in the kitchen for preparation and cooking. But still there is dissatisfaction among the users for adoption or using it completely. The problem

lies in the design of user interface, which creates a fear in the minds of consumer to use it completely. While using the microwave oven the users are facing lot of problems which are related to buttons, knobs, switches, touch screen, etc., provided in user interface which is depicted in Table 1. Proper font size and style are important attributes for the UI readability. So the paired preference test was conducted to find out the readable font size to be used in the buttons of the user interface. From the results of paired preference test it was seen that best combination is black font in white background and white font in black background. It is in accordance to the study by Hinum [5] that high contrasts are difficult to attain with colour combinations other than black and white. This is the reason printed material is usually most readable in combination of black and white. So, while using colour combinations one should be very careful and use colour only for highlighting of regions or aesthetic reasons. Same font size i.e., 6.5 was used for all the selected colour combinations. The results of the paired preference test were experimentally tested by using eye tracking method for which stimuli was prepared to test the parameters. Through eye tracking experiment also the same results were obtained that is white font in black background was more preferred combination by the respondents. Hence, it can be concluded that for information processing in the user interface, with white font in black background is easier than other combinations.

5 Conclusion

From the study it can be concluded that the market is flooded with consumer electronic products and people are dependent on these products. These electronic products are meant to make the lives of users comfortable but the consumers face many problems while using it. It may be due to not involving the users in designing the product. An effort had been made to generate a framework of guidelines, to be considered while designing user interface of consumer electronic products. It was evident from the study that consumers are aware about their requirement for ease of operation of the Consumer Electronic Product. Hence, under the study effort has been made to generate guidelines based on consumer needs through data generated by conducting workshop, usability workshop like eye tracking experiments. These guidelines can be used for product development.

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Interrelation of Multiple Intelligences—An Approach to Enhance Learning

Tulika Borah, Juri Baruah, and Amiya Ranjan Bhowmick

Abstract Howard Gardner's multiple intelligences (MI) theory claim that the capacities of every individual are unique due to the range of different intelligences possessed by them. The theory has been widely accepted but, there are still gaps in its application. Variations that prevail within the learners should be recognized and acknowledged, so as to enhance learning. This paper investigates the types of intelligence possessed by 120 primary school children of age 8–11 years. It focused on determining the inter-correlation among the seven variables of intelligence theory. Both quantitative and qualitative methods were used to collect information from the samples. The results indicated that the number of children who possessed bodily-kinesthetic and spatial-visual intelligences were more as compared to other types of intelligences. Correlation analysis revealed significant positive correlations among the intelligences, except Intrapersonal-Bodily-kinesthetic and Intrapersonal- Interpersonal intelligences, which were found to be negatively correlated. Further the results of an exploratory factor analysis revealed three factors—F1 (Spatial-visual intelligence, Logical-mathematical intelligence, Bodily-kinesthetic intelligence), F2 (Music, Linguistic) and F3 (Interpersonal, Intrapersonal) that grouped the variables. The findings indicate that recognizing the profile of intelligence is extremely important, since one type of intelligence support the other.

Keywords Multiple intelligence · Types of intelligence · Inter-correlation of intelligence

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1 Introduction

The concept of intelligence has changed over the years depending on the context of its use. Generally, intelligence is viewed as a cognitive capacity to accomplish any task.

Howard Gardner introduced Multiple Intelligences (MI) theory proposing that there are several independent ability areas. He suggested that all human beings possess different intelligences in varying degrees and each individual manifests these intelligences differently, thus each person has a unique blend of intelligences. Gardner also pointed out that intelligences do not work independently but always interact with one another.

Research conducted by Campbell and Campbell [1] on multiple intelligences gave evidences of the usefulness of multiple intelligence approach in education. He explained that MI approach influences educator's belief about student's intelligence and achievement; also students can learn the subject matter in variety of ways. Thus in teaching–learning process, it is important to consider the fact that every individual is unique, has individual profiles of intelligence. Many other researchers have also suggested the importance of empowering students by identifying their profiles of intelligences [2–5].

The purpose of this paper is to assess the prevalence of different types of intelligence proposed by Gardner in his MI theory and to analyze inter-correlations among the intelligences. If every individual has exceptional properties and inner potentials making each one unique, then there must be diverse combinations of these intelligences. The ways in which such intelligences are combined to carry out different tasks may vary depending on the blends of intelligences possessed by individuals. The present study envisages that assessment of multiple intelligences and inter-correlations within different types of intelligences will help in improving performance of children in various domains. The objectives of the study are

i. To assess the types of intelligence prevalent among children.
ii. To analyse inter-correlation of multiple intelligences.

2 Materials and Methods

2.1 Research Design

The research design followed in the present study was Embedded mixed method design. Creswell and Plano Clark [6] posited that embedded design is used in cases where quantitative data are collected simultaneously with qualitative data or vice-versa, and when a type of data play supportive role to the primary data. The supportive data may be either qualitative or quantitative. In the present study, quantitative data collected from the respondents were supplemented by qualitative data, analyzed

and interpreted simultaneously, which justifies the use of Embedded mixed method research design.

2.2 Sample

The sample for this study consisted of 120 numbers of school going children belonging to the age group of 8–10 years. The data were collected from three semi-urban schools of Jorhat district, Assam. Respondents were selected through simple random sampling technique. The averages BMI of children were 16.7 kg/m^2 (height 123.9 cm; weight 25.7 kg) and 17.2 kg/m^2 (height 130.2 cm; weight 29.2 kg) respectively for age 8–9 years and 9–10 years. The income of majority of respondents were in the range of Rs. 50,000–100,000 per annum.

2.3 Techniques of Data Collection

Multiple intelligences test: For quantitative assessment a multiple intelligence test was used. The test consisted of 35 items based on seven types of intelligence namely—Visual-spatial, Bodily-kinesthetic, Musical, Interpersonal, Intrapersonal, Linguistic, Logical-mathematical. Scores were given against each item in four point scale: mostly disagree, slightly disagree, slightly agree and mostly agree. The scores obtained by a respondent in all the seven types of intelligence were compared. The type of intelligence with highest score was considered as the dominant intelligence type of that particular child.

Observation and interview: In addition to quantitative method of data collection, qualitative methods were used to supplement and validate the data collected through quantitative method. Respondents having different types of intelligence were observed during their leisure period. Individual interviews were also conducted to collect additional information on type of intelligence.

3 Materials and Methods

3.1 Assessment of Types of Intelligence Among Children

The type of intelligence possessed by children was assessed based on the multiple intelligences (MI) test, observation and interview reports. Observations were made in school during leisure period. Armstrong [7] suggested that good observational indicator of students' proclivities is how they spend their free time in school. The

Table 1 Distribution of respondent children according to their type of intelligence

Type of intelligence	Frequency	Percentage
Linguistic	17	14.17
Logical-mathematical	14	11.67
Musical	19	15.83
Bodily-kinesthetic	23	19.17
Spatial-visual	22	18.33
Interpersonal	13	10.83
Intrapersonal	12	10.00

Number of respondents (n = 120)

observations were carefully noted and analyzed. Children were interviewed individually to collect information on type of intelligence. Open ended questions were asked like—What do you like to do when you have free time? What do you do after you reach home from school?

Finally, data gathered through quantitative and qualitative techniques were computed to assess the type of intelligence possessed by children. The scores obtained by children in MI test were matched with the findings of observation and interview. Those children who did not have distinctly high score in a type of intelligence or who had similar scores for two or more types of intelligence were not considered. The distribution of respondents according to their type of intelligence is shown in Table 1.

It was found that the percentage of respondents having bodily-kinesthetic intelligence (19.17%) was more than other types of intelligences; it was followed by spatial-visual intelligence (18.33%).

3.2 Inter-correlation of Multiple Intelligences

Karl Pearson's Correlation test was performed among seven different types of intelligences on a set of 120 samples. The results show that correlations between 13 out of 21 pairs of intelligences were statistically significant.

Bivariate scatter plots between two intelligence types are plotted below the diagonal with a simple linear regression line overlaid. The diagonal entries represent the distribution of individual variables with kernel density estimator overlaid. Above the diagonal, the correlations are presented (Fig. 1).

Exploratory factor analysis (EFA) was conducted to determine the number of distinct unobservable latent variables. It was revealed that a few types of intelligence were closely correlated thereby forming groups within themselves. Parallel analysis of the correlation matrix was carried out to obtain the distribution of the eigenvalues and the scree plot gave the three optimal numbers of factors. This method compares the scree of factors of the observed data with a random matrix of the same size

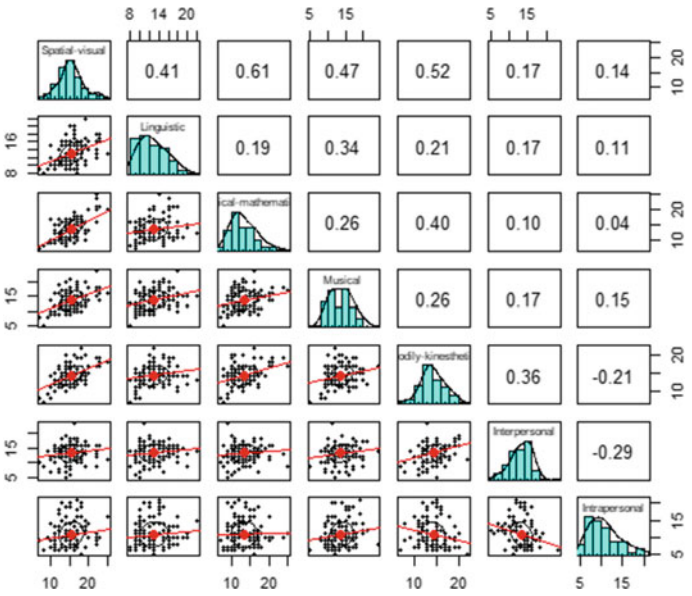

Fig. 1 Inter-correlation of intelligence types

simulated from the joint distribution of the given data matrix. The nFactors package available in R software for statistical computing was utilized to perform the analysis [8].

Strong positive correlations were found between spatial-visual and logical-mathematical intelligences r = 0.61 ($p < 0.01$), followed by spatial and bodily-kinaesthetic intelligences r = 0.52 ($p < 0.01$); spatial-visual and musical intelligence $r = 0.47$ ($p < 0.01$); and spatial-visual and linguistic intelligence r = 0.41 ($p < 0.01$). A moderate positive correlation was found between linguistic intelligence and musical intelligence $r = 0.34$ ($p < 0.01$) but the correlations between linguistic and bodily-kinesthetic intelligences $r = 0.21$ ($p < 0.05$) and linguistic and logical-mathematical intelligences $r = 0.19$ ($p = 0.04162$) were found to be weak. The correlation between linguistic and interpersonal intelligences $r = 0.17$ ($p = 0.07095$) and linguistic and intrapersonal intelligences $r = 0.11$ ($p = 0.2372$) were found to be non-significant. Non-significant correlations were found between spatial-visual and interpersonal types of intelligences $r = 0.17$ ($p = 0.06654$) and spatial and intrapersonal intelligences $r = 0.14$ ($p = 0.115$). Negative correlation was found between interpersonal and intrapersonal intelligences $r = -0.29$ ($p < 0.01$).

Figure 2 shows exploratory factor analysis of the variables. The psychological relevance of the factors is given in the text. The factor analysis, using the varimax rotation, revealed that the three factors group the variables as follows: F1 (Spatial-visual intelligence, Logical-mathematical intelligence, Bodily-kinesthetic intelligence), F2 (Music, Linguistic) and F3 (Interpersonal, Intrapersonal).

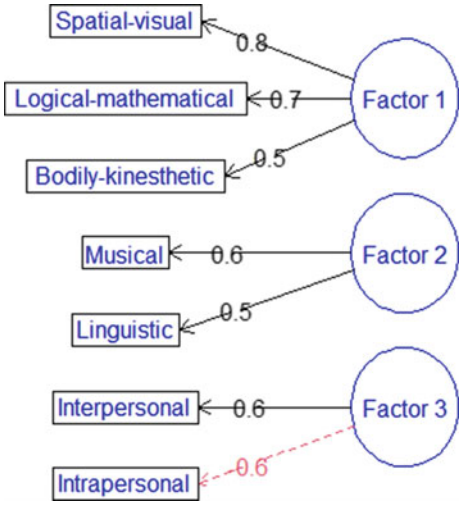

Fig. 2 Exploratory factor analysis of the variables

4 Discussion

4.1 Assessment of Types of Intelligence Among Children

It was found in the study that maximum number of children possessed bodily-kinaesthetic intelligence as dominant type of intelligence. Bodily-kinaesthetic intelligence is related to body movements and control. Children often engage in activities that require physical movements like running, jumping, climbing, cycling, dancing, physical exercises, sports and other activities requiring physical movements. Children derive pleasure by involving themselves in such physical activities and they may like to learn in a way that is pleasurable. Hence, the scopes to use bodily-kinaesthetic intelligence were more. Another reason may be that children get enough opportunities to involve themselves in physical activities as they belong to or have contact to rural areas and so the environmental conditions might have added towards the development of bodily-kinaesthetic intelligence. Kolb's theory of learning styles explains that learning styles arise out of genetics, environment and experiences confronted [9]. This theory can be applied in case of occurrences of a particular type of intelligence. The genetic predisposition, life events and the environmental conditions, all influences the type of intelligence a person possesses [10].

The second most frequently prevalent type of intelligence found among the respondents was spatial-visual intelligence (18.33%). Children gather information through exploration, experimentation, observation and imitation. While doing so they gather certain experiences which remain with them in the form of mental images. These mental images are reproduced and applied in real life situations. This visual-spatial process of mental imagination becomes so obvious for children that they frequently use spatial skills in different types of day to day activities. Children engage

in variety of play and they use spatial skills while playing. Many research studies have also reported the use of spatial skills in everyday life to playgrounds [11–13]. This may be the reason behind the second highest prevalence of spatial intelligence in children.

Children having interpersonal (10.83%) and intrapersonal (10%) types of intelligence were found to be the least. The reason may be that children having interpersonal intelligence interact with friends and adults well and get appreciation for the quality, but do not realize it as their capacity. Similarly, children may choose to be within themselves and to be self-regulated, but they do not realize it as their type of intelligence. Hence, many children may fail to self-assess themselves as interpersonal and intrapersonal types of intelligence. The type of self concepts a person have, may influence in self-evaluation of multiple intelligence [14, 15].

4.2 Inter-correlation of Multiple Intelligences

The findings of the present study can be supported by various research studies. A number of research studies have indicated about correlation of spatial intelligence and mathematics [14, 16]. Studies have also stressed about spatial reasoning as basis to mathematical works [5, 17, 18]. Research also suggested that spatial reasoning and spatial representations become more important as one advances in learning mathematics [19, 20]. The correlation between spatial-visual and bodily-kinaesthetic intelligences can be explained through the fact that spatial concepts such as sense of distance are learned through movement and active exploration. Cognitive studies claim that many cognitive activities that were earlier believed to be purely "cognitive" were found to be ingrained in body related experiences with the environment. It was observed during the study period that children having bodily-kinaesthetic intelligence showed hand, body and head movements while performing spatial tasks. Studies have revealed that people 'think kinaesthetically' [13, 21–23].

Factor analysis, using the varimax rotation depicts that three type of intelligences i.e. bodily kinaesthetic, spatial-visual and logico-mathematical intelligences form a group. People with frequently apply extrinsic-static spatial skills while solving mathematical problems as numbers essentially have spatial relations. Bodily-kinaesthetic intelligence is related to one's ability to use body or body parts in performing a task. As humans are mobile organism, children move and explore their world. Movements and physical activities help in all round development of children [4]. For every movement, rhythm, coordination and mental imagination are necessary. Suppose while walking from one place to another, one has to mentally calculate the distance to be covered within a time frame and accordingly set the speed of body movement (walking speed). In this action, a person is applying spatial intelligence (mental imagination), logico-mathematical intelligence (calculating speed and distance) and bodily kinaesthetic (coordination of body movements) intelligences. In many activities of everyday life coordination of these three types of intelligences are involved. Research also suggests that body gestures improve spatial thinking and reasoning

[24]; spatial thinking and reasoning are important for mathematical understanding [17].

The inter-relation between music and language is a well-known fact. Research in cognitive science agrees that there are important connections between music and language. Research findings suggest that musical structure is processed in language areas of the brain [25]. These research evidences are aligned to the findings of this study.

It was found in the study that interpersonal and intrapersonal intelligences are negatively correlated. Intrapersonal intelligence deals with knowing about oneself and interpersonal intelligence is about understanding others. This shows that the basis of these two types of intelligences are different. Pishghadam [11] described that, while intrapersonal intelligence is in regards to one's own feelings and emotions, the interpersonal intelligence enables one to know others' desires, feelings, and intentions. Similar to the present study, negative correlation was found between interpersonal and intrapersonal intelligences in a study conducted by Bay and Lim [26].

5 Conclusion

It was evident from the study that children possess different types of intelligences and there were inter-correlations between the types of intelligence in various ranges. Correlations of types of intelligence in varying degrees indicate that every person possesses all types of intelligence in varying amount. The findings of this study are aligned with Gardner. He suggested that every individual possess all intelligences in different extents, with scopes of further development. He asserts that use of any type of intelligence depends on the preference and need of individual to use it. Schools should not merely focus on the strengths of children, but also be able to identify the weaknesses in order to help each child to overcome problems in learning. Multiple intelligence theory gave a basis to acknowledge the array of differences found within the learners. It is indeed essential to understand that, all types of intelligence are important, as they work together or separately depending on the situations. Having a strong intelligence does not mean that the person will necessarily excel in that field. It depends on how a particular intelligence is supported by other intelligences and how different types of intelligence coordinate with each other to accomplish a task. Hence, it can be concluded that profiling of intelligences is necessary to assess the combinations of intelligence possessed by a child and nurture accordingly.

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Understanding the Usability of School Stationery and the Scope for Innovation

Jay Khopey, Ayush Srivastav, Tejal Kalgutkar, and Siddhartha Mukherjee

Abstract Geometrical construction refers to a precise way of drawing and measuring lines, grids, curves, and angles using appropriate tools. This paper discusses a new design of a ruler, targeting school students, that equips the users with a single tool that can perform most of the essential geometrical functions at a non-commercial accuracy. Students are introduced to geometric tools in 5th grade. Although the most basic geometry box available in the market today consists of a 15 cm ruler, a compass, a divider, 2 set squares, and a protractor, some of these tools are rarely used. Having several tools also increases the cognitive load on the users and hampers portability. Moreover, carrying the whole set isn't always feasible, and thus, the users tend to lose tools at crucial times. Pre-existing multifunctional rulers, at times, fail to serve their purpose as they can be devious to work with and overcomplicate simple functions. These insights are backed by our user research, collecting data from a sample size of over 350 users ranging from 10 to 65 years of age, spread across multiple disciplines. These problems can be readily solved with an all-in-one solution, that fixes these issues. The newly designed instrument, which is in its user testing phase with a sample size of 15, is an L-shaped ruler, intended to measure distances and draw straight lines like a conventional ruler and construct and measure different angles, perpendiculars, and parallel lines, thus effectively eliminating the need for set squares and protractors and making it highly portable.

Keywords Scale · Guides · Protractor · Multipurpose · Geometric instrument · Try square

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1 Introduction

Last three decades transformed the system of using tools and instruments in schools and colleges as they updated their curriculum with time, but the geometrical tools used in schools have remained the same. Geometric tools are used to draw lines, figures, shapes, diagrams and grids accurately and neatly. They are also used for verifying and marking lengths and angles. Most of the education boards in India prefer using three major tools from the geometry box- ruler, compass, and protractor, while the other tools in the box are rarely used efficiently in a classroom scenario. Heilbron [1] Oxford introduced a geometry box as a set of geometric tools, which included two set squares, a 180° protractor, a 15 cm ruler, and a metal compass, which has been used for generations of students across the world and the same set of instruments are still being used in India without any changes till date. The multifunctional geometric tools, that intend to serve all functions in one tool, end up being complicated because of their ineffective and unfamiliar designs (pt. 10, Table 2, page no. 8). This gap between old geometry sets and all in one tools leads to an opportunity of requisitioning and redefining the existing tools, understanding their applications and uses and incorporating the same in new, more efficient tools without making them over complicated.

2 Approach

To understand the usability of school stationery and the scope for innovation, we started with an initial research with a sample size of 350 with people from a variety of age groups and backgrounds using geometric tools. According to [2] "The Effect of Geometry Box Media on the Ability to Know the Concept of Numbers and Geometric Shapes" and [3] "Analyzing the need of math geometry drawing tools in mathematics classroom", we identified a need gap with lack of innovation in terms of geometric supplies for school students despite the large part that geometry plays in a child's development. We defined our users as young adults and school students who are actively using geometric tools and narrowed down the sample size for further research to 30 students from 8 to 12th std. from different states and curriculum boards in India. After evaluating the current use case scenarios of the geometry box at the elementary and high school level we received user assessed feedback. This was followed by synthesis of data collected during research which was used to derive design directions for ideation towards solutions.

3 Research Methodology

The primary aim was to explore how geometric tools were used and carried and why they are designed the way they are. The same geometric tools have been used for decades in school stationery with no major changes in design. Many companies made changes in graphics of scales (set squares, protractors and rulers) for making it easy to read and use but the basic set remained the same. In this research, we aimed at verifying the need for the existing set of tools by requisitioning its usability as school stationery (Fig. 1).

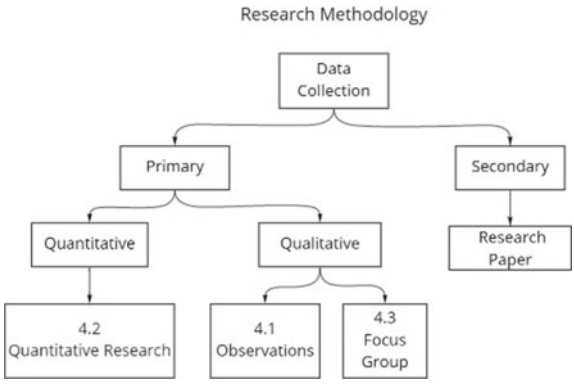
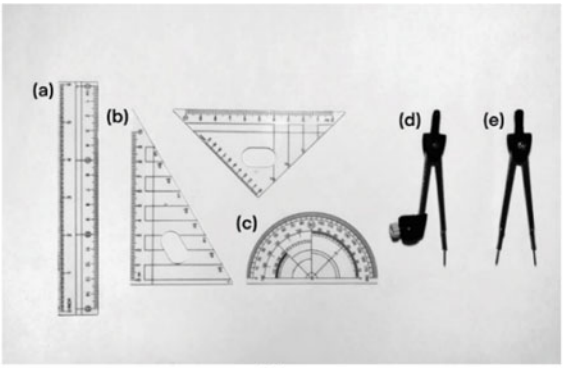


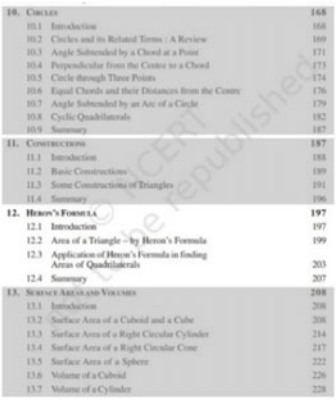
Fig. 1 Flowchart depicting the approach followed in research methodology

4 Research Outcomes

4.1 Observations



(a)



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10.4 Perpendicular from the Centre to a Chord 173
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12.2 Area of a Triangle – by Heron's Formula 199
12.3 Application of Heron's Formula in finding Areas of Quadrilaterals 203
12.4 Summary 207
13. Surface Areas and Volumes 208
13.1 Introduction 208
13.2 Surface Area of a Cuboid and a Cube 208
13.3 Surface Area of a Right Circular Cylinder 214
13.4 Surface Area of a Right Circular Cone 217
13.5 Surface Area of a Sphere 222
13.6 Volume of a Cuboid 226
13.7 Volume of a Cylinder 228

(b)

(c)

(d)

Fig. 11.9

3. Bisect these angles. Let the bisectors of these angles intersect at a point A.
4. Draw perpendicular bisectors DE of AP to intersect PQ at B and FG of AQ to intersect PQ at C.
5. Join AB and AC (see Fig. 11.9).

Then, ABC is the required triangle.

EXERCISE 11.2

1. Construct a triangle ABC in which BC = 7cm, ∠B = 75° and AB + AC = 13 cm.
2. Construct a triangle ABC in which BC = 8cm, ∠B = 45° and AB – AC = 3.5 cm.
3. Construct a triangle PQR in which QR = 6cm, ∠Q = 60° and PR – PQ = 2cm.
4. Construct a triangle XYZ in which ∠Y = 30°, ∠Z = 90° and XY + YZ + ZX = 11 cm.
5. Construct a right triangle whose base is 12cm and sum of its hypotenuse and other side is 18 cm.

(e)

Fig. 2 **a** 15 cm ruler (**a**), set squares (**b**), protractor (**c**), compass (**d**), divider (**e**). **b** NCERT [4] class 9th mathematics textbook NCERT. **c** 15 cm ruler on an A5 students' notebook. **d** Arrangement of tools in geometry box. **e** NCERT [4] geometry questions from a NCERT Mathematics text book

1. Ruler, protractor, set squares, compass and divider are the most common tools used for construction (Fig. 2a).
2. More than one third of the syllabus in mathematics textbooks has topics related to geometry (Fig. 2b).
3. In school, mathematics questions are solved in A5 notebooks or A4 registers (Fig. 2c).
4. Geometry box is the most common way for systematically carrying geometric tools as it has defined spaces for individual tools to fit in (Fig. 2d).
5. The questions (problems) in geometry text books do not have any questions asking for construction more than 15 cm (Fig. 2e).

4.2 Survey to Determine the Pattern of Usage of Geometric Tools

A simple quantitative survey was conducted on the lines of descriptive research on people's interaction with geometrical tools that helped us in understanding the usability of the tools and identifying problem areas. The online survey with structured questions was circulated among a large and varied group of students/users to ensure that the information collected can be statistically inferred from a diverse user population.

We then came up with observations from this survey, that collected data from a sample size of over 350 users ranging from 10 to 65 years of age, spread across multiple disciplines (Figs. 3 and 4).

This survey contributed towards defining the brief of the project by narrowing down the user group and problem statement.

4.3 Focus Group (Interview)

Interviews were conducted to help us empathize with our users by gaining a better understanding of their experiences and point of view for deeper insights on their interaction with the geometric tools. Based on the previous survey, the users were narrowed down to school student because this is the group with the most requirement for geometric tool set for academic purposes and thus makes up the largest market. The sample size of 30 users chosen for this interview comprised students from classes 8th to 12th from schools of different curriculum boards of India. The interviews were conducted on video calls with open-ended questions where we encouraged the students to talk about their perceptions and experiences with the tools (Fig. 5).

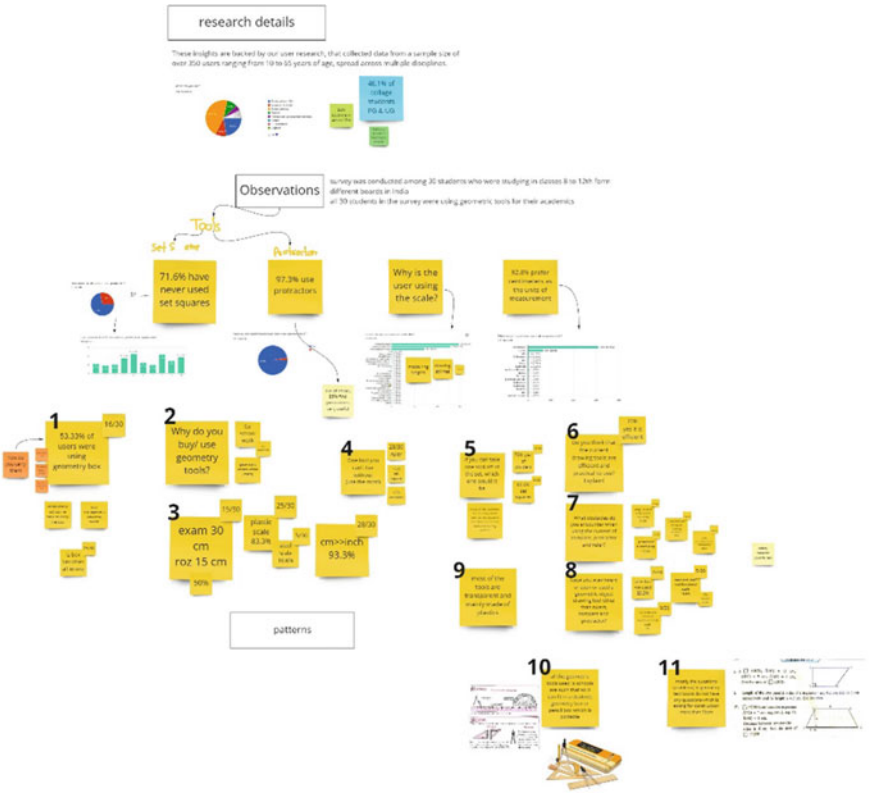


Fig. 3 Research - brainstorming with data and questionnaire (findings and explanations in Tables 1 and 2)

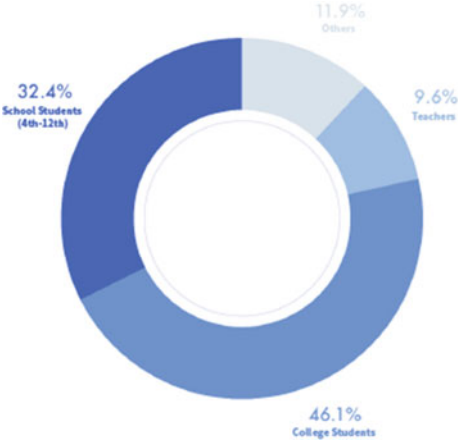


Fig. 4 Demographic for quantitative research (sample size—357)

Table 1 Observations from quantitative survey

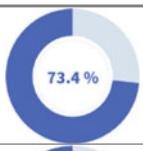
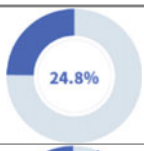
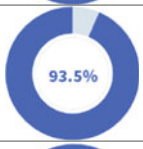
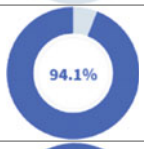
	Number of users using the tool	Users who find the tool useful
Set square		
Protractor		
Ruler		

Table 2 Observations from qualitative research with the focus group (interview)

S. No.	Questions		Answers	
1	Why do you buy/use geometric tools?		• Academic requirement	
			• Mathematic construction	
2	Do you think that the current drawing tools are efficient and practical to use?		• Yes	70%
			• No	30%
3	What are the most used or functional tools in your set? (MSQ)		• Ruler	100%
			• Protractor	86.6%
			• Compass	90%
4	Why do you use (MSQ)	Ruler	• Measuring lengths	96.6%
			• Drawing straight line	100%
			• Cutting/tearing paper	23.3%
			• Drawing perpendiculars	16.6%
		Protractor	• Measuring and constructing angles in degrees	100%
		Compass	• Constructing angles	96.6%
			• Making circles and arcs	100%
			• Used as a substitute divider	10%
		Set square	• Drawing perpendiculars and angles	30%
			• Drawing parallels	10%
			• Never used	70%
5	What obstacles do you encounter when using compass, protractor and ruler?		• Tough to pick up scales from flat surfaces	
			• Protractor is confusing	
			• Scratches on scales	
			• Markings vanish	
			• Safety hazards due to pointed tips of compass	

(continued)

Table 2 (continued)

S. No.	Questions	Answers	
6	What do you feel is the least important tool?	• Divider	70%
		• Set square	66.6%
7	How do you buy geometric tools?	• Geometry box	83.3%
		• Separate tools	10%
		• Value kits (ruler, compass, protractor)	6.7%
8	How many geometry boxes have you bought in 3 years?	• 1–2 boxes	43.3%
		• 2–3 boxes	46.7%
		• 3 or more	10%
9	How do you store and carry your geometric tools?	• Geometry box	53.3%
		• Others	46.7%
10	Have you ever heard seen or used any geometric tools other than the basic set?	• Seen but not used	83.3%
		• Not seen not used	0%
		• Used (foldable scales, scale with protractor, scales with stencils, etc.)	16.7%

Fig. 5 Research - brainstorming with questionnaire and data collected

5 Analysis

Synthesis of the data collected during the research helped us come up with the following insights.

5.1 Insights

Ergonomics

- Measuring scales (ruler, protractor) are difficult to pick up from flat surfaces.
- Visual clutter of markings (readings) leads to cognitive overload.
- Geometry box helps in proper organization of tools as it has slots for individual tool to fit in.
- Carrying two boxes (pencil box and geometry box) makes the school bag heavier.
- Carrying individual tools makes them prone to breakage.
- Plastic scales with soft edges are safer than metal scales with sharp edges.

General Use

- Plastic scales are readily available.
- Plastic scales which are transparent ensure more accurate measurements as it allows a clear view of the object to be measured.
- According to 93.3% of the users, a 15 cm ruler is the most important tool in a geometry box as it is handy and used very frequently.
- Multifunctional tools that closely resemble conventional tools (foldable scales, scales with stencils etc.) are more likely to be accepted and used because of the familiar and simple designs.

Product Efficiency

- Divider is not used as it is not introduced properly in the curriculum.
- Students use compass as a substitute for dividers.
- Set squares are rarely used as its function of drawing perpendiculars can be easily achieved using a compass or a protractor.
- Although most of the multifunctional tools solve the issues of portability, they are rarely used as they are not cost effective or user friendly and there is a lack of availability.
- Existing multifunctional scales can get overly complex to use because of their unfamiliar and complicated designs.

5.2 Design Direction

- Efficient and sustainable packaging with a revised set of useful tools.
- A geometric tool kit with a revised set of tools.
- Working on the forms of existing tools to make them more efficient.
- A multifunctional tool eradicating seldomly used tools and increasing the efficiency and practicality of existing tools with simple innovations maintaining familiarity with the existing conventional tools.
- Decreasing cognitive load by incorporating better visual hierarchy.
- Experimenting with different materials and finishes to meet sustainability goals.

6 Addressing the Scope for Innovation

The insights helped us in identifying opportunities and gaps which can be addressed through innovation with the aim to achieve simple and efficient geometric tools to be used in schools. This is accomplished by ideation on the defined design directions.

6.1 Ideation

The ideation phase based on design directions focuses on generating as many concepts and ideas as possible (Fig. 6).

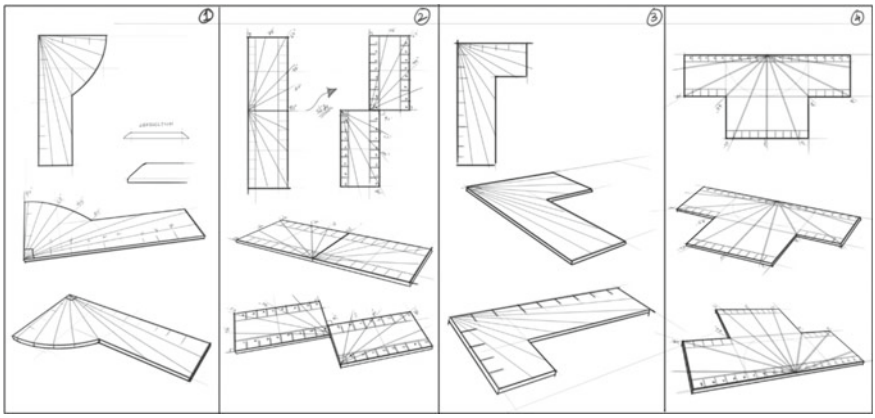


Fig. 6 Ideation

6.2 Final Concept

The ideation was concluded with an L-shaped ruler (Fig. 7) which is currently in its user testing phase with a sample size of 15 people.

The new design measures distances and draws straight lines like a conventional ruler. It can also be used to construct and measure different angles, perpendiculars, and parallel lines (Fig. 8), providing an effective alternative for replacing set squares and protractor, thus making it highly portable.

The final concept is under further development (Fig. 9).

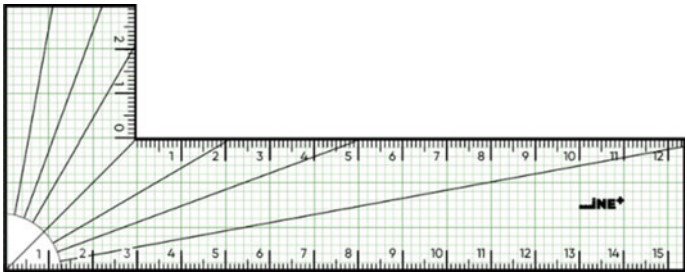


Fig. 7 The proposed concept in the form of an L- Scale

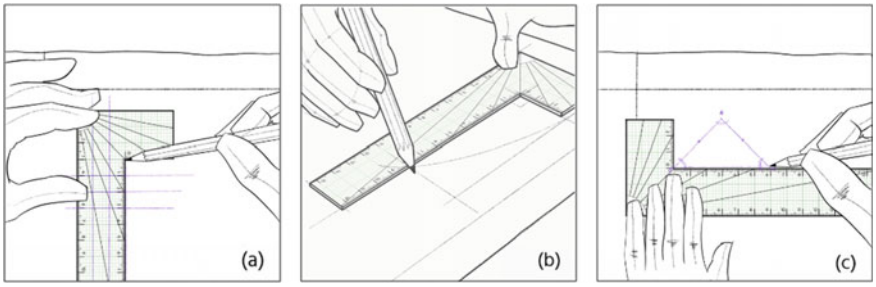


Fig. 8 User scenarios for L-scale depicting human interaction. **a** Drawing straight lines, grids, and margins. **b** Constructing perpendiculars. **c** Constructing angles (protractor)

Fig. 9 User testing of L-scale with 15 students from DBRK Vidyalaya, Kamptee

6.3 Design Decisions (L Scale)

- Familiar form.
- Multifunctional tool eliminating the need for multiple tools.
- Dimensions and size can easily replace tools and be accommodated in the established systems of geometry boxes.
- Visual hierarchy in markings decreasing cognitive load.
- Transparent scale providing a view of the work-surface.
- Grids for reference.

7 Conclusion and Future Direction

7.1 Conclusion

- Geometry box is a set of tools used in schools and on an average, a student buys more than three geometry boxes over his/her academic years. During this time almost one third of the syllabus covered in mathematics textbooks includes topics related to geometry. The most basic geometry box available in the market today comprises a 15 cm ruler, a compass, a divider, a pair of set squares, and a protractor, even though some of these tools are rarely used. Having several tools also increases the cognitive load on the users.
- Carrying the entire set is not always feasible, as a separate toolbox is used to carry these tools safely, which increases the bag weight and hampers portability. Pre-existing multifunctional rulers that tried to solve these problems, at times, failed to serve their purpose as they can be devious to work with, have unfamiliar designs and tend to overcomplicate simple functions.
- This research identifies the opportunities and needs for innovation presented by the gap between old geometry sets and the multifunctional tools by requisitioning the existing set of tools, understanding their applications and uses and generating solutions by ideating to achieve more efficient tools without making them over complicated by maintaining familiarity with the conventional tools.

7.2 Future Direction

Validating the final concept and refining it further based on the user testing for a simple, cheap and efficient geometric tool targeted at school students and young adults. Working on the form and materials, clutter free markings with visual hierarchy, manufacturing and packaging for making the product more tangible and market ready.

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Engaging Design Projects: A PBL Framework for the New Normal Communication Design Education

Nanki Nath

Abstract Communication Design has witnessed novel approaches and methods of teaching learning in context of the new normal needs. Project Based Learning (PBL) courses in Graphic Design have seen novel hybridization formats to explore with other design disciplines. In the new normal times, graphic design (communication design students) at NID Ahmedabad could undertake 'Engaging Design Projects' based on Blended teaching–learning methods, such as: Individual/ Skill-Based Rotation Blended Learning, Flex Blended Learning, Flipped/ Remote Blended Classes and Supplemental Learning Activities as part of the instructions-cum-exchange format for two 'Design Projects' modules conducted by the researcher for her M.Des students of Graphic Design at NID Ahmedabad (2020). Each student took forward his/her core strength areas among design domains in graphic design, such as: Storytelling, Illustration, Indigenous Letter Design/ Indic Typography, Digital Content Curation and Design, e-book-making, Strategic Systems Design, Navigation and Image Building, Branding Local Spaces/ Ventures, etc. The project outcomes showcase a process-to-solution journey presented and reviewed in three project reviews organized and final documentations submitted for each of these Design Projects. The present paper proposes a PBL framework applied that is constructed of 4- Pillars: Pitch, Process, Product and Performance. Each pillar includes blended teaching–learning methods, core strength areas and the respective learning outcomes; and the assessment approaches developed in conducting these Engaging Design Projects. This PBL framework envisions future opportunities of Blended Learning for Engaging Inter-disciplinary design projects for developing project-based learning cum instructional design pedagogy for communication design education.

Keywords Design projects · Project Based Learning (PBL) · Engagement methods · Communication design · Blended instruction · Design education

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1 Introduction

1.1 Project Based Learning (PBL)

Revisiting the roots of the PBL: it all started from the likes of Prof. Adam Kinory, a high school humanities teacher. He initially just layered technology over his teaching and realized that he didn't reinvent the classroom [1]. The 'big leap' happened by merging his hands-on experiences in digital media with The Digital Edge Learning Interchange[1] [2]. His students were video-makers. Therefore, he demonstrated how to embed digitized clips directly into their documents, linking visual imagery with written analysis. PBL is reinvention of collaborative learnings, quality of design projects and meaningful opportunities to engage within real-time projects.

The author as an faculty anchor[2] applied PBL for two core Design project Modules for M.Des graphic design curriculum at NID Ahmedabad, 2020. Continua to Consider for Effective PBL model approach [3], allows a faculty to harness a project experience by sliding towards students' learning parameters (Fig. 1a).

The faculty anchor took elemental leads from the model of K12 education [4]. The 3 DPs in M.Des, Graphic Design programme making are based on revision of the project based classroom structure (see Fig. 1b).

This fundamental redesign of the instructional model (1b) aimed to achieve following characteristics of Blended learning [3] in the DPs model (Fig. 2):

(1) Co-creation activities for scaffolding students strengths and interests—to increase the interaction among students, students with their individual project guides, students with anchor faculty, students with project stakeholders and students' increased interest to bring outside, relevant and established resources/knowledge in the co-creation activity times.
(2) An Integrated formative and summative assessment mechanism for students as 3 depth review presentations and written feedbacks postreviews were followed by the anchor faculty for both DPs.

Design Projects (DPs) at NID are part of a semester-driven project experience ecosystem—that connects semester-wise learnings through the three M.Des DPs as containers of learning. This paper has a special focus on DP-III [Visual Strategies for Communication Systems) and DP-II [Context and Information Systems] conducted for M.Des18 and M.Des19, Graphic Design batches in the Covid-19 times of 2020 via online learning modes (Fig. 2).

[1] An online library that exhibits of exemplary classroom practice involving varied applications of analog + digital technologies on a range of subject areas and levels —elated to the International Society for Technology in Education (ISTE).

[2] Faculty Anchors are the 'facilitators' who moderate, plan, manage and deploy certain teaching–learning inputs as part of PBL approach specially applied for project-based courses—wherein, students select, execute and submit the outcomes and validation of a certain real-time design problem/need/scenario, etc. as individual design projects at NID.

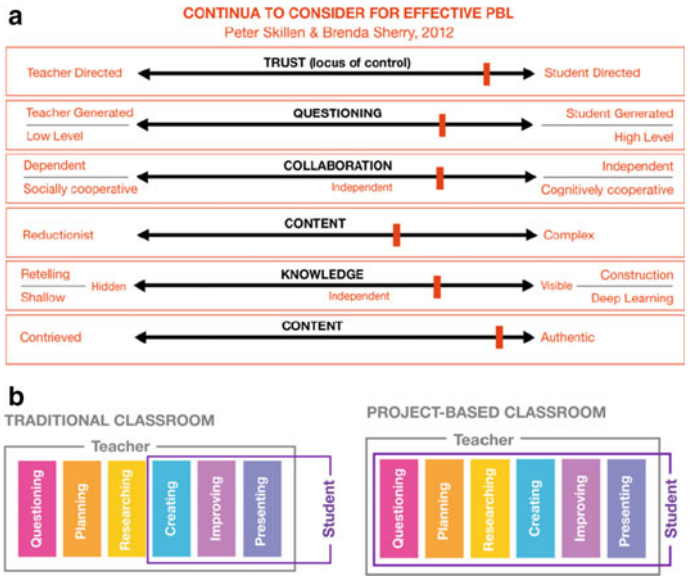


Fig. 1 **a** Continua to consider for effective PBL used in projects by Sherry and Skillen, 2012. **b** Traditional versus a project-based classroom by k12.thoughtful learning

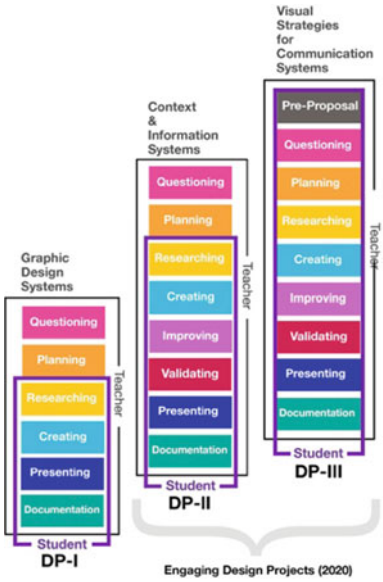


Fig. 2 PBL classroom: revised k12.Learning: online DPs, Graphic Design, NID (2020)

1.2 Engagement Redefined for New Normal Design Projects, NID

If Engagement improves achievement, then those teaching strategies are needed that not only feed students interests; but also improve their cognitive abilities as subject leaders. PBL is one such methodology that research suggests can effectively improve these via inquiry-based learning through authentic questions and problems within real-world practice [5–9]. PBL made each DP an EDP: Engaging Design Project in the new normal year 2020, and may be defined as follows:

Engaging Design Project is an online, action-based, inclusive distance-learning project that integrates active interactions, blended learning and assessments with respect to the essential modes units of engagement: Pre proposals, Questioning, Planning, Researching, Creating, Improving, Validating, Presenting and Documenting. Their occurrence and sequence may be linear or non-linear depending upon the need and the design problem context as part of an EDP.

The aim and objectives as part of DP-III course contents.

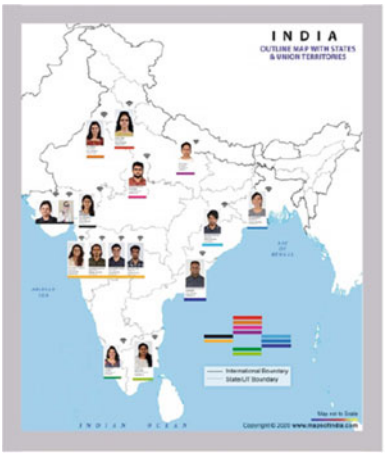
Batch: M.Des18, Semester 4 | Graphic Design | 10 weeks EDP | Dec'19–April 2020

- To develop students' systemic thinking skills for design applications involving visual strategies in developmental communication: social context projects.
- To facilitate critical feedbacks for students on how to approach the design problem(s), target audience needs and sustainable systemic practices in their projects.
- Validation and Testing of the graphic designs and strategic outcomes within a feasible real-time scenario/space concludes the EDP with future scopes to be included in documentations.

The aim and objectives as part of DP-II course contents.
Batch: M.Des19, Semester 3 | Graphic Design | 8 weeks EDP | Aug–Dec 2020

- Engaging EDP formats for new normal PBL: such as course welcome videos, DP course materials including inclusive maps (Fig. 3), etc. instructional design by Anchor Faculty.
- To empower the students with the recent digital tools and techniques for projects encircling digital ecosystems[3] and facilitate them for preparing pre-proposals.
- In the new normal scenario of increased modes of communication and digital channels / touch-points for interactions, students are encouraged to blend designs with new graphic design practices and validate with the users.

[3] Design projects targeting digital ecosystems include a feature, release or other digital asset of a product/ design solution fitting in the platform of a brand or how the user interacts with that solution. These systems are about providing, regulating, supporting and enhancing the channels which use the system. It is not about one channel, it is about the connection between these channels, and how they interact with each other.



Name	Student ID	Location
Divya Lohia	S1901101	Delhi
Amogh Bhatnagar	S1901102	Gwalior, Madhya Pradesh
Sushmita.V	S1901103	Chennai, Tamilnadu
Jyoti Poonia	S1901104	Kohina, Churu, Rajasthan
Tanusree Debdas	S1901105	Kolkata
Saloni Khanvilkar	S1901106	Mumbai
Sneha Majumdar	S1901107	Ahmedabad
Nikita Jaiswal	S1901108	Varanasi, Uttar Pradesh
Lakshman Shashikant Khadapkar	S1901109	Mumbai
Mahindra Prasad Tudu	S1901110	Rourkela, Sundergarh, Odisha
Sherina Siraj	S1901111	Kerala
Seethina Satya Siva Kanth	S1901112	Visakhapatnam, Andhra Pradesh
Rohit Subhash Pawar	S1901113	Mumbai
Mustafa Zaveri	S1901114	Navi Mumbai, Maharashtra

Fig. 3 Inclusive EDP Maps for course welcome: DP II of GD M.Des19, NID (2020)

1.3 Learning to Learn: The 4Ps in the Making

Dziuban, Hartman, and Moskal (2004, p.3) have described blended learning as—"a pedagogical approach that combines the effectiveness and socialization opportunities of the classroom with the technologically enhanced active learning possibilities of the online environment." From students' perspective, the socialization, active-interactions and new knowledge help them up-skill their strengths and competencies. Hybrid learning[4] provides both the students and teachers with home location flexibility, phased decision-making and inclusivity in project themes [10]. The standard parameters that were laid out for engaging design projects in new normal times included: Skill-based, Perception-based and Self-guided learnings as part of Process and Performance, Flipped group-based and Supplemental group-based learning activity sessions conducted by anchor faculty as part of first two weeks of the EDPs for Pitching and planning Ideation Process (Sect. 2 and Fig. 12). These as part of 4Ps were the final evaluation criterion for each EDP.

The aim behind Hybrid learning involving both students and the faculty anchor has been Learning to Learn.[5] Knowledge prepares us to develop in our present world; but, above all, it must prepare us to adapt to the changes around us. In this context, the method of Learning to Learn is applied in project-based courses to target transformations in teaching methodologies and also engagement based learning methods

[4] Hybrid learning can be defined as a learning approach that combines both remote learning and in-person learning to improve student experience and ensure learning continuity. Refer: https://en.unesco.org/sites/default/files/unesco-covid-19-response-toolkit-hybrid-learning.pdf

[5] Learning to Learn is that role of education that provides us with knowledge in the broadest sense includes the necessary concepts, theories around them, methods of applying them, the technology that help us in their practical use and the ability to acquire new knowledge in the future. Refer: http://www.dccia.ua.es/pe18/PBL_english/posing_a_change_in_teaching_methodology.html

Fig. 4 Continua for online PBL: towards the 4Ps framework for EDPs, NID (2020)

that students undertake to apply to pitch (project proposals) and harness new process in design projects; following the 4 Ps (Fig. 4).

The four steps of the sub-aims are based on (Fig. 4) are as follows:

- Understand and Envision: build a **Pitch**
- Decide and Design: construct through a **Process**
- Enable and Execute: facilitate students' for detailing out the **Product**
- Monitor and Adjust: manage project assessments + revisions in **Performance**

2 Blended Learning: Mixed Methods for EDP Modules at NID

2.1 Online EDPs

They involve a mixed-method approach to blend different teaching learning methods, modes and tools as follows:

2.1.1 Individual Cum Skill-Based Rotation Blended Learning

Faculty Anchor utilized the dual rotation modes to integrate online Face-to-Face (oF2F) brainstorming workshops for project selections in the first 4-days of the first week for both DP II and DP III with the individual project showcase per student in entire second week. In DP II, the projects showcased each student's jamboard project pitch and a complete EDP proposal (Fig. 5 captures an EDP that explored Display Graphic + Museum Design + Outreach Event to blend Graphic Design + Exhibition Design practice). In DP III, a pre-proposal[6] and complete EDP proposals were sub- mitted and separately discussed with anchor faculty and faculty guides.

In this regard, the video meet has been an engaging tool to facilitate extended and flexible communication between anchor faculty-students and students-guides. They

[6] Pre-proposals are five to six page draft of 'an idea of a project'— including the design problem and elabo-rations for the problem-based approach aid the design process for DP-III module students at NID (2020).

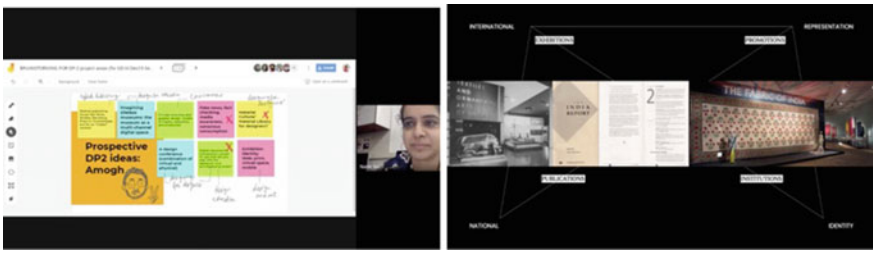


Fig. 5 Jamboard brainstorming of a DP II: PITCH level-1: project selections and proposal

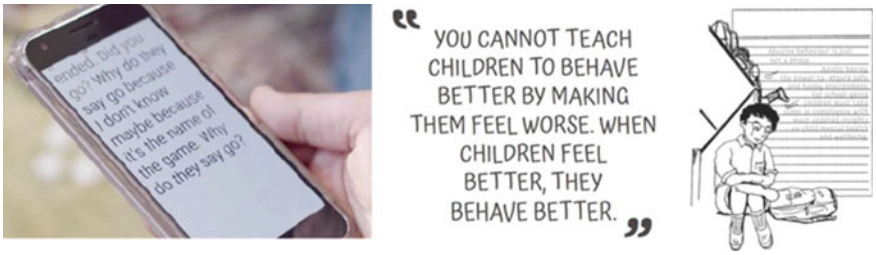


Fig. 6 Live transcribe (left) used by Manali in her DP III: 'helping school children combat negative impacts of bullying'

break long-distance barriers with short break-in rooms via google meets, zoom used in few extra interactions with students who needed visual cues, verbal discourse and paraverbal communication[7] [11], [to help a DP-III M.Des student who had a speech and hearing-impairment—a paraverbal aid provided by Google's Live Transcribe (Fig. 6) alongwith the Google Meet subtitles provisions].

2.1.2 Flex Blended Learning

Flex learning approaches provided with a fluid form of teaching–learning and have been effective in the main research-to-ideation weeks for both DP II and DP III. The use of ICT helped form study networks where students interacted through educational use of social networks and platforms. For instance, some students for their EDPs formed focused-activity through Official Instagram (Fig. 7a and b).

Contextual/Situational mapping: co-learning-based generated process through workshop modes included a bouquet of contextualizing methods: experience/journey maps, opportunity mappings, shadowing, etc. applied as per a project (Fig. 8a and b of a contextual mapping with DP II students).

[7] Paraverbal refers to the all that we say through the tone, pitch and pacing. It is how we say something that accounts for approximately 38% of what gets communicated. Refer: CADRE [Center for Appropriate Dispute Resolution in Special Education].

Fig. 7 **a** Instagram user research (right) by Vaibhav Nanchahal for his DP III: 'To explore the possibilities of the revival of Gurmukhi and the Punjabi language'. **b** Instagram user research (right) by Bhavyajeet Gehlot for his DP III: 'Never Loose a Thing'

Fig. 8 Context-based prompt for choosing context factors: contextual mapping workshop for DP-II (8a). Contextual Mapping of the Visitor journey for designing a virtual museum | DP II of Amogh Bhatnagar, NID, 2020 (8b)

2.1.3 Self-Guided Flex: Students Utilizing the Educational Cloud

Flex learning approaches provided with a fluid form of teaching–learning that have been effective in the main research-to-ideation weeks for both DP II and DP III.

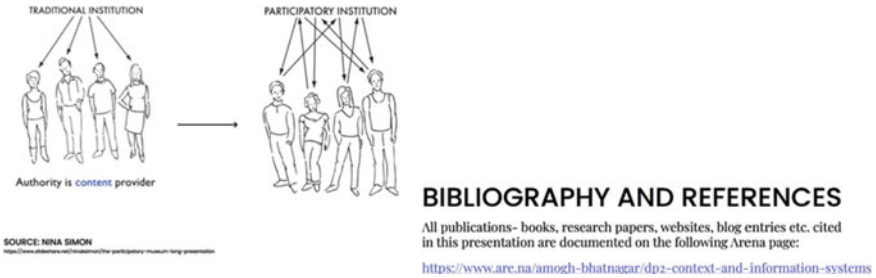


Fig. 9 Self developed and curated e-resource database by Amogh Bhatnagar, NID, 2020 for his DP II

The use of ICT helped form study networks where students interacted through for EDP courses, NID's e-resource portal[8] during Covid-19 embraced diversity and inclusivity for tapping and securing books, etc. from known, established publishing organizations/bodies as per the kind of project per student This type of technological innovation has led to a competitive and avant-garde approach to modern education [12]. This progressively prepared students for better management and utilization of technology for project benefit and they devised self-curated digital libraries / e-resource tools for self-databases as well (Fig. 9).

2.1.4 Flipped / Remote Blended Learning

Continued in-class activities and project questioning, planning and research stages with anchor faculty made utilization of Conversational framework by Diana Laurillard, 2002 [13, 14]. The spirit of the model highlights a deliberate approach to augment learning in minds and develop 'better engagements' between students and teachers; alongside gaining expertise in technology-specific skill sets at students' end (see Fig. 10). The same base framework also became a useful aid for students to prepare structured and semi-structured surveys with their target users as part of their projects 'process'.

2.1.5 Supplemental Blended Learning via a Robust Triadic Reviewing System

EDP Reviewing System had multi-disciplinary faculty members as review panel as supplemental facilitators to critique student projects. The critiques gave feedbacks on the 4Ps; alongwith suggestions of resources/ experts from academia/industry for projects. In 2020, for both DPs, one panel member from Exhibition, Product,

[8] e-resources by NID's library for remote access by students and faculties outside campus – provided a detailed depth-resource of e-databases and e-journals (2020) amidst the Covid-19 pandemic distance learning continuous educational programme.

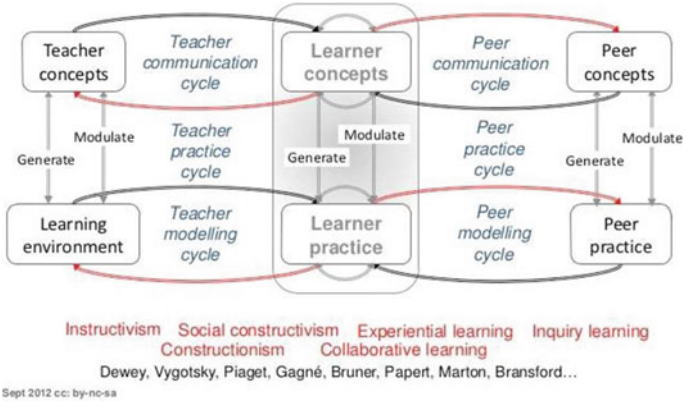


Fig. 10 Established conversational framework by Diana Laurillard, 2002 | *Source* Rethinking University Teaching: a framework for the effective use of learning technologies

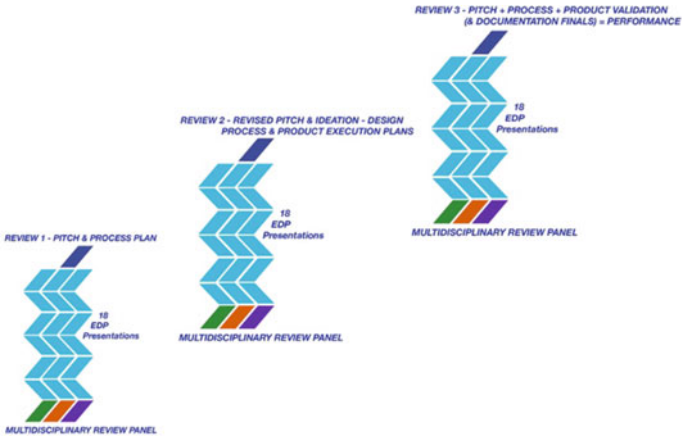


Fig. 11 The triadic reviews (1,2 and 3) for DP II and DP III M.Des batches, Graphic Design, NID (2020)

Photography and Animation Film Design was invited. This enriched the supplemental learnings with the blend of online reviewing expertise with the presentation upskilling and collaborative learning of students (Fig. 11).

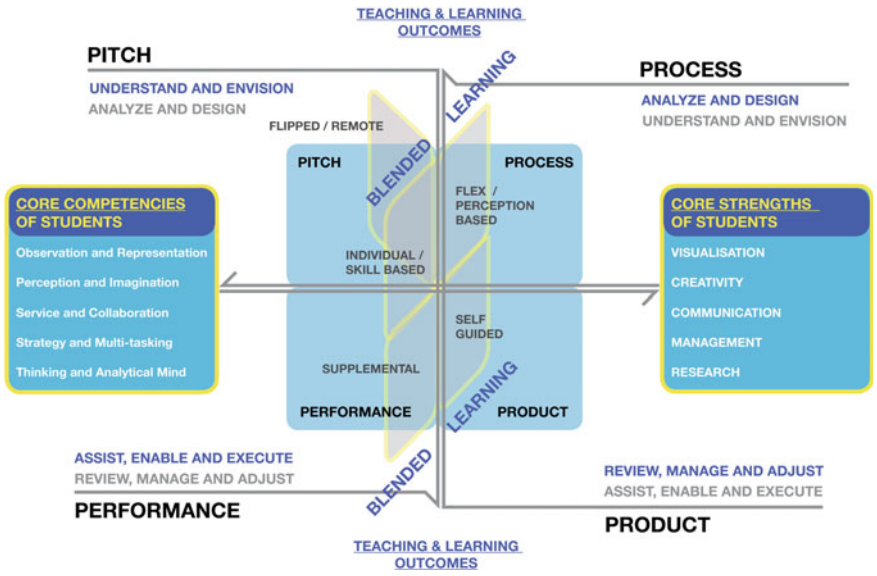


Fig. 12 The 4 Ps framework: for PBL-oriented engaging design projects [EDPs] and similar project-based courses in communication design education for the new normal pedagogy

3 4 Ps Framework of EDPs in Communication Design (2020)

3.1 4Ps Framework: The Whole is the Sum of It's Parts

The 4 Ps: Pitch, Product, Process and Performance as part of each DP II and DPIII for each of the 36 students (18 students and projects per batch) of M.Des, Graphic Design, NID in 2020 incorporated a blend of following PBL units (Fig. 12).

Teaching and Learning Outcomes mutually aimed for students' centric as well as student-faculty, anchor-guides collaborative learning.

- **Core Strengths of Graphic Design students** in both the batches discussed by faculty anchor with students—inclined strongly towards students' future areas of interest as part of their portfolio for placements.
- **Related Skills / Core Competencies of Graphic Design students** include the existing as well as aspirational skills, competencies and higher objectives that the students' and the anchor faculty aimed to achieve through the Pitch-Process-Product-Performance primary PBL units of EDP construct.
- **Blended Learning tools and methods / Hybrid approaches** as elaborated in Sect. 2, have been the instrumental thrust for re-defined Pitch and refined/ revised Process and Product making plans as part of Review 2 and 3 presentations of both batches in their EDPs (Figs. 11 and 12). Each student took forward his/her

core strength areas among design domains in graphic design, such as: Storytelling, Illustration, Indigenous Letter Design/ Indic Typography, Eco-friendly Packaging Design, Digital Content Curation and Design, e-book-making, Strategic Systems Design, Navigation, etc. after mapping her/his Core Strengths and Related Skills / Core Competencies.

3.2 The Domain Axis: The Horizontal and the Vertical Axis in the Framework

- **Horizontal axis** included projects of 18 students per batch AND their faculty guides giving focused and descriptive feedbacks, supervision, assistance in the core subject area—that helped each student set the first 2Ps: the Pitch and Process critically within the objectives and higher learning objectives of PBL. Anchor faculties with multi-disciplinary faculty reviewers conduct the triadic reviews for EDP students to access Product and Performance (Figs. 11 and 12).
- Hybrid format combined all PBL stakeholders and their value aspirations from the EDP. Hence, the **Vertical axis** includes good scope of honing single or a blend of skills with existing/ aspired core competencies in the selected subject area of graphic design chosen by all the students in the batch in discussions with faculty anchor—as an outcome of the first week (Figs. 5 and 6) and post review-2 workshops (see Fig. 8a and b).

3.3 The Innovation Aspect: 4 Ps Framework for Project-Based Learning

- Teaching and Learning Outcomes involved different parameters depending on each of the 4Ps stages for each of the 18 EDPs as part of the two Design project modules conducted.
- The Pitch and Process (first two Ps) set the maximum momentum and rigour; with the flipped learning in terms of co-creation workshops, thinking aloud sessions, collective students' synthesis activities on Miro boards, etc. with anchor faculty.
- This led to the Product and Performance improvements: enabling student to acquire core-competencies through detailed three review presentations.
- Executions helped augment the core strengths of visualization, creativity, research, communication, etc.—for which individual guides as prime role players and anchor faculty as secondary facilitator contributed.
- The 4 Ps achieved an innovative take the moment a detailed plan of strengthening core competencies (on x-axis) was channelized through the outcome aims set for all 4 Ps to invent a new normal teaching–learning paradigm.
- Vertically mapped in the 4Ps visualization, the teaching–learning paradigm has a strong backing of all the blended learning methods adoption, flexible applications

depending on projects and validations in the Product and Performance as part of the 3 reviews + project documentations submitted by students.

4 Future Scope: 4 Ps Framework for Inter-Disciplinary EDPs

Online / Distance learning has captured the new normal needs to a prominent extent. It is perhaps among the fastest growing trends in the educational uses of technology for tapping accessible learning-based project opportunities. If applied effectively to future design projects under the inquiry-based research umbrella of human-centered design—may help establish a sustainable eco-system, aid businesses and enable health care infrastructure, etc. for future generations. Designers (from all multi-disciplines) need to be proactive and build the real pulse of collaboration with an inter-disciplinary mindset for present day new normal as well as post-covid scenarios. This line of thought prompted the faculty anchor and M.Des18 students target developmental communication projects (social context projects) in their EDP in 2020. Further cause-based learning would justify in a better way by bridging the gap and foster long-term partnerships between the multidisciplinary EDP designers and other stake holders in real projects—including scientists, engineers, architects, urban designers, programmers, coders, conversation designers, sociologists, psychologists, historians, structuralists, linguists, etc.

In the present realm of uncertainty, a collaborative and blended perspective from activities to assignments to workshop modes to learning outcomes that we generate for courses in communication design may implement the 4 Ps rooted in PBL for inter-disciplinary design project-based learnings for students.

Acknowledgements This paper is dedicated to all Masters in Design, Graphic Design students of 2018 and 2019 batches—who undertook PBL courses of DP III and DP II respectively that anchored as a faculty member, 2020 at NID Ahmedabad.

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Efficacy of Sex Differences on the Perceptual Experience of Virtual Building Images

R. D. Sambath, Sharmili Mitra, and Manish Kumar Asthana

Abstract The current study focuses on the perceptual experiences of Indian males and females on structurally significant buildings. Environmental perception is based on the contextual significance or imposed meaning of environmental elements and built structures. Cognitive psychologists have extensively researched how individuals respond to various social circumstances. However, scarce studies examine the socio-psychological factors which reflect male and female perception of the virtual models. In total, 99 healthy individuals were volunteered, and each was assigned images of 17 virtual buildings along with five key questions to respond on a 10-point Likert scale (a total of 85 presentations). Participants answered five questions about identifiability, comfort, male-centric, environment space, and place sociability of the structurally significant buildings. The virtual building perception significantly varies between male and female participants. Males rated significantly higher on the level of comfort and level of male-centric compared to females. The results indicate sex biasedness on the perceptual experience of virtual buildings. Findings also suggest the efficacy of sex differences in social, cultural, and gender preferences in selecting virtual models.

Keywords Perception · Building-models · Virtual-reality · Sex-difference · Male-centric · Environment

1 Introduction

Prolonged stay at one place results in a person–place bonding or a place attachment [1]. People find meaning and memories with those places they are attached to, and it is easy to recall their favorite places and buildings with clear structure and differentiation [2]. A meaningful built form is considered a work of architecture or a structurally significant building [3]. We could determine architectural importance or structural significance altogether by its design (functional or aesthetics) and method to construct (style, form, material, and craftsmanship) [4, 5]. People determine their

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surrounding architecture based on their personal experiences [3], which is a function of several socio-personal factors. Hence structurally significant buildings can explain architecture with emotional, physical, intellectual, aesthetic, social, religious, cultural, and economic meaning for people and society.

Psychologists have extensively researched how individuals respond to various environments and built structures they experience in daily life. Modern tools like virtual reality (V.R.) have played an essential part in human behavioral research for the last few decades [6, 7]. The V.R. consist of a virtual environment, which is the composition of various virtual environmental features or virtual models. The selection of virtual models in these environments generally follows an identification task (object reorganization) or name agreement task based on the familiarity of the stimuli and their resemblances to real-world objects [8, 9]. There have been fewer previous studies examining the socio-psychological contexts of virtual architecture models. Hence, the current research focuses on five fundamental social components attached to structurally significant building models in the Indian context. The primary concern was the identifiability of the given building models: to what degree a 3D virtual model is identifiable and resembles the actual building. The identification task is mainly aided by the model's visual features and experience with a particular architecture represented by the virtual models. Generally, people first attend visual features (such as surface finish, color, and shape), and then objects appear to them in a later phase [10]. Hence, both the physical features of models and the user's subjective experience have a vital role in the selection process of virtual architecture models. While discussing the subjective experience, the Perceived level of comfort and Place sociability are the other two main factors to consider while selecting a structurally significant 3D building model.

A sense of comfort offers an optimistic, active, moral, and humane context for a place [11, 12]. Moreover, the comfort level addresses several aspects: safety, cleanliness, and seating choice, whichever gives the first impression about a place. We see people walking, sitting, watching events, singing and playing music, and walking together in more open and comfortable areas [13]. People are easily drawn to open spaces that provide a sense of comfort [14]. The sociability of a space can be described as its comfort and openness, which allows users to engage in various cultural and social activities [1, 15, 16]. People engage in various activities if they have an opportunity to find and occupy their space in a place or a community. Hence, people's option to occupy themselves or sit could be a synonym for an active place that can be taken to measure the quality of a sociable outdoor public space [13]. A friendly and sociable place should also provide equal opportunities for all users, irrespective of race, gender, or creed. Their sex greatly influences human presence, perception, and preferences towards different objects [17]. Sex equality has an important implication on assessing the quality of life in a place or a community [18]. The study also emphasizes perceived sex difference to analyze the dominance of sex and the significance of 3D representational virtual building models [19].

It is essential to verify the sociability factor while selecting stimuli for a socio-psychological study. This study aims to select virtual architectural models in the following five primary social contexts: identifiability, level of comfort, perceived

sex difference, the place to sit, and place sociability. The study also interrogates how people rate images of structurally significant models, mainly the sex-related influences in virtual building models' perception.

2 Materials and Method

2.1 Participants

The overall sample consisted of 99 participants (mean age = 25.7; SD = 6.6; 44 female) who voluntarily participated in the Google survey circulated through social media networks. Exclusion criteria were physiological problems (hypothyroidism, diabetes, polycystic ovary syndrome, allergy, vitamin D deficiency, Etc.), psychological abnormalities, and a history of epilepsy. Further, participants who failed to achieve > 5 values in 50% of the trials were also excluded. The final sample (N = 53) consisted of 22 females (42.30%) 18–35 years of age (M = 23.68, SD = 5.01) and 31 males (59.61%) 18–35 years of age (M = 24.81, SD = 5.67) from different parts of India. 64.15% of respondents reported being undergraduates, 16.98% were postgraduates, 16.98% were Ph.D. students, and the remaining 1.88% were intermediate students. Informed consent was obtained from the participants that specified that participation would be voluntary, i.e., participants may refuse to participate without any loss or benefit. The protocol for the study was approved by the Institute Human Ethics Committee (I.H.E.C.), Indian Institute of Technology Roorkee (Protocol No.: BT/IHEC-IITR/2020/7004/11).

2.2 Stimuli

The structurally significant virtual models were obtained from the 3D warehouse library of Google Sketch Up (3dwarehouse.sketchup.com). As the concept of structural significance is culturally bound, we have chosen building models that are prominent in the daily life of the Indian population. Models were then exported as JPEG with a resolution of 1033 × 464 pixels for an image rating survey to check the acceptance of these structurally significant buildings. The selected building models consist of three mosques, three temples, three churches, three hospitals, three schools, and two clock towers. Examples of objects are presented in Fig. 1.

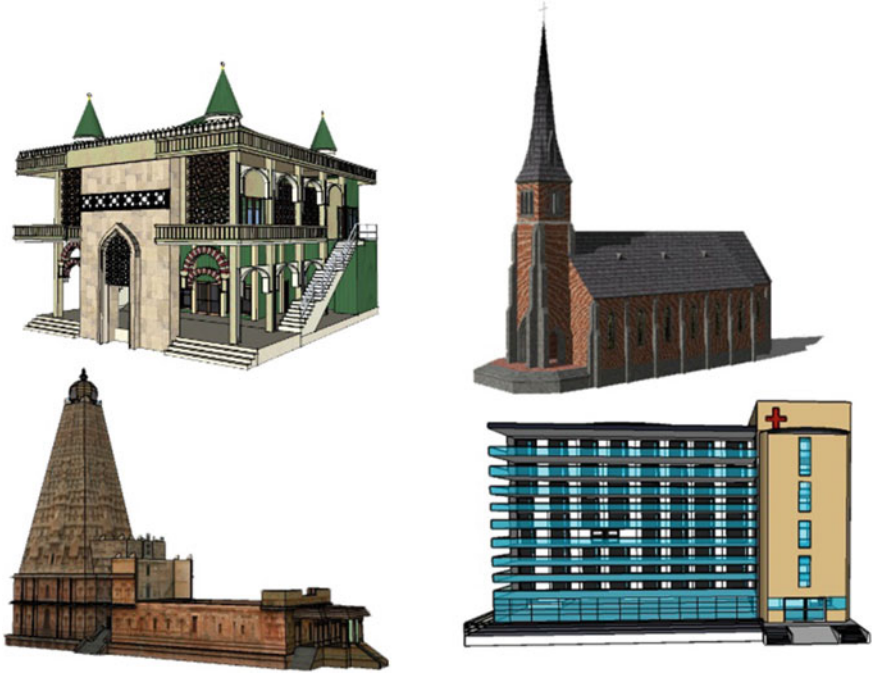

Fig. 1 Examples of stimuli as exhibited in the online study

2.3 Procedure

The online survey was conducted using Google Form (https://www.google.com/forms), an easily accessible open-source platform. The survey consisted of three main sections, including an informed consent section, a demographic section, and a main image ranking section. Participants were first requested to report informed consent, and then the demographic section with 13 questions, including age, sex, education status, state of residence, history of medical or psychiatric illness, and the number of caffeine drinks consumed on the day of the survey. The image ranking section consisted of five subsections, where each subsection included the images of selected 3D building models. Subsections are: -

Identify the given building models. The participants were requested to rate an image of virtual models of buildings on a 10-point Likert scale stretching from 1(not at all) to 10 (completely). for example, a mosque's image was followed by a question, "Is this a mosque?".

Perceived Level of Comfort. Participants were asked to rate an image of 3D building models with the question, "Do you feel comfortable at this place?" on a 10-point Likert scale ranging from never to always.

Table 1 Statistics of the sample

	Female (10)	Male (18)	*F*	*p*	*d'*
	M (S.D.)	M (S.D.)			
Age (years)	24.81 (5.67)	23.68 (5.01)	0.56	0.46	0.21
Pre-arousal	5.58 (2.83)	5.68 (1.89)	0.21	0.88	0.04
Pre-valence	6.32 (2.18)	6.27 (1.58)	0.01	0.93	0.03
Post-arousal	6.23 (2.58)	6.05 (1.50)	0.87	0.77	0.08
Post-valence	6.65 (2.20)	6.00 (1.51)	1.42	0.24	0.34

Means (M) and Standard deviation (S.D.) for both males and females, and statistics for one-way ANOVA.

The Perceived Sex Difference (i.e., male-centric). Participants were demanded to rate the level of perceived sex difference associated with the building models on a 10-point Likert scale ranging from never to always.

The Perceived Place for Sitting. Participants were asked to subjectively rate the place for sit on the buildings' surroundings in the image on a 10-point Likert scale ranging from never to always.

Place Sociability. Participants were requested to subjectively rate the level to which the buildings appear to be sociable on a 10-point Likert scale varying from never to always.

Table 1 outlines the demographic characteristics of the age and sex of participants. There is no significant difference found in the pre and post-arousal- valence scale used in the study. But we observed that the mean value of valence rated by males decreased from pre to post-survey.

3 Data Analysis

Data collection for the study was performed using Google Forms. Each participant was assigned an identification code to maintain confidentiality, and data was sorted using Microsoft Excel. Statistical Package for Social Sciences (S.P.S.S.) version 20 was used for data analysis (I.B.M.; United States). It has been documented that ordinal data with normal distribution one could perform the ANOVA test. We conducted the ANOVA test for two reasons: (i) large sample size and (ii) data with normality [20, 21]. We performed a one-way analysis of variance (Sex × V.R. Models) [6 architecture categories (mosques, temples, churches, hospitals, schools, and clock towers)]. Further, we analyzed the effect size of both groups' ratings and computed

using Cohen's d [22]. The ANOVA results did not show a statistically significant effect of sex on the identification of 3D virtual models, but statistical significance on level of comfort and perceived sex difference was observed.

4 Results

Kolmogorov–Smirnov normality test (Table 2) revealed the normal distribution for the three variables (male-centric, place for sit, and place- sociability); however, two variables (identification of the landmark and level of comfort) demonstrated a significant *p-value*.

In the current study, we use an alpha value higher than 0.05. We further did the Kolmogorov–Smirnov normality test for both sexes separately, and we found that the female data set rejected the null hypothesis for non-normality. For males, three variables (rejected the null hypothesis, while two variables (identify and comfort) revealed significant effect. These data sets had high socio-cultural aspects.

The ANOVA results associated with virtual building image rating across male and female groups in five different conditions—identification of the landmark, level of comfort, perceived sex differences, place for sitting, and place-sociability were analyzed. It can be seen that the perception of sex inequality is observed for the virtual models of Church 2, Temple 2, and the three schools. It has been observed that both male and female participants identify these buildings to be more androcentric than other virtual buildings. The results also point out a significant difference in the perceived comfort level of Mosque 3, Church 1, and Hospital 1.

4.1 Identification of Building Models

Survey questions were asked to study the ability of participants to identify the images of virtual buildings. Each of the 17 stimuli was rated by both male and female participants. Results showed that participants were very familiar with the stimuli (M = 9.2, SD = 1.6; scale: 1–10). We found no difference in the mean rating of

Table 2 Tests of normality

Underlying distribution	Kolmogorov–Smirnov test ($\alpha = 0.05$)				
	Identifiablity	Comfort	Male-centric	Place to sit	Sociability
Total sample (53)	< 0.001*	0.02*	0.20	0.20	0.20
Normal male (31)	< 0.001*	0.04*	0.20	0.20	0.20
Normal female (22)	0.20	0.20	0.20	0.20	0.20

The table presents the *p*-values of variables, where * = *p*-value ≤ 0.05.

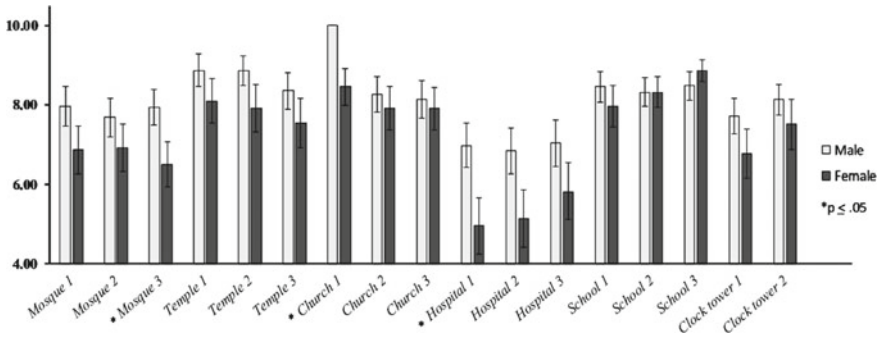

Fig. 2 Level of comfort regarding images of building models

identification of buildings by both males and females ($p > 0.05$ with a moderate effect size $d < 0.5$ for the images of virtual buildings).

4.2 Level of Comfort

It was found that there was a significant variation in the perception of the level of comfort among males and females for the Virtual Models- Mosque 3, Church 1, and Hospital 1 (see Fig. 2). This is supported by 2 (Sex x VR Models) analysis of variance which reveals that there was a significant main effect of sex in case of Mosque 3 [$F(1,51) = 3.99$, $p = 0.051$, $d = 0.56$], Church 1 [$F(1,51) = 15.76$, $p = 0.00$, $d = 1.11$] and Hospital 1 [$F(1,51) = 5.08$, $p = 0.029$, $d = 0.63$]. These virtual models were perceived to be more comfort five different conditions than the other models.

4.3 Perceived Sex Difference (i.e., Male-Centric)

The conditional question "Are there more men than women?" was used in the study to understand the perceived sex differences or the predominance of one sex over the other in the buildings represented using images. A significant main effect of sex was witnessed in the virtual models of Temple 2, Church 2, School 1, 2 and 3 (see Fig. 3). The 2 (Sex x Virtual Models) analysis of variance shows that the participants perceive that there are more males than females in Temple 2 [$F(1,51) = 4.88$, $p = 0.032$, $d = 0.61$]; Church 2 [$F(1,51) = 4.49$, $p = 0.039$, $d = 0.59$]; School 1 [$F(1,51) = 136.71$, $p = 0.00$, $d = 3.26$]; School 2 [$F(1,51) = 10.46$, $p = 0.02$, $d = 0.9$] and School 3 [$F(1,51) = 7.02$, $p = 0.11$, $d = 0.74$].

One-way ANOVA showed that participants' perceived place for sitting and the sociability of virtual buildings shown in the images was lower for females than male counterparts. However, there was less effect of sex on the perception of both places

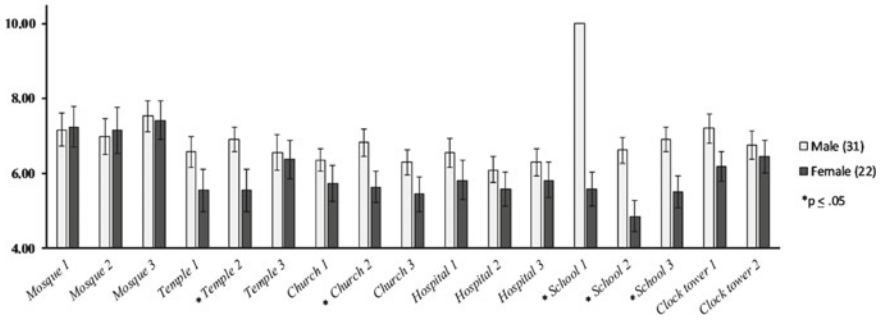

Fig. 3 Perceived sex difference on images of building models

for sitting and place sociability factors ($p > 0.05$ with a moderate effect size $d < 0.5$ for the images of virtual buildings). For example, the difference between the mean rating of male 6.97 (SD = 2.83) and female 6.32 (SD = 3.09) for sitting in mosque 1 [$F(1,51) = 0.206$, $p = 0.652$, $d = 0.22$) is very small.

5 Discussions

The current study results recommend that sex differences might be one of the contributing factors in the preference of 3D virtual building models in all five conditions. The significant sex difference was found mainly in the perceived level of comfort and perceived sex difference related to virtual buildings representations. However, the study found no influence of sex difference on identifiability criteria, the place to sit, and the sociability of the place. The identifiability of the virtual model in the present study yielded a result similar to that familiarity measure from the virtual objects of previous studies [8, 9]. It was easy for participants to recognize the features of 3D virtual building models. We found that male dominance has a significant effect on the preference for virtual building images.

The places and objects that a user occupies and their occupancy context give different meanings to space. A physical place is a space incorporated with different cultural expectations and appropriate behavioral variations. Space becomes a place according to how we use it [23], or human activities give life to space and make it a place. One can stay in a place for some duration only if a facility of sitting is provided. Here, staying for some time means staying for a while and allowing the performance of numerous prime attraction activities in public space, such as reading, sleeping, talking, playing, eating, and so on. These activities have a significant role in public space quality in a city or a residential area [13]. An outdoor environment's quality can be improved simply by creating more and better seating provisions [13]. Further studies could explore in this direction to examine the correlation of quality

of the environment and structural significance with more number of participants and with more building models with structural relevance.

Regarding the perceived level of comfort related to places represented by 3D virtual models is found more significant in this survey. For instance, the female perception of comfort in the hospital is lower than that of males. Generally, women experience more pain and experience more communication issues with healthcare providers, and they feel less comfortable with healthcare workers [24]. The sense of comfort of both males and females in temple, church, and mosque is also significant in this study. Both sexes chose visual representations of church 1, which possesses more structural characteristics of a typical Indian church, which is perceived as most comfortable than the other two churches. Hence the study also reveals that structural significance correlates with the level of comfort of the building, regardless of the intended purpose. Moreover, the cultural value binds structural significance in the built form in our daily life. Future researchers may develop and validate stimuli in a social context for such socio-psychological experimental studies.

The sociability of a place is an essential element that allows people to occupy and use any public place. Zakariya and collaborators (2014) described sociability as an ability of people to become attracted and connected to a place that allows them to perform different social and leisure activities as individuals and groups. This study uses images of virtual building models to examine sex influence on place sociability. Even though we chose attractive building models in our daily life, the results show no significant effect of sex. Perhaps this might be because the building models we presented were devoid of any background. Additionally, the factors such as the total layout, the placement of each element, change of levels, provision of suitable open and green spaces, and visibility play a vital role in determining the sociability of a place [15].

A recent study shows that taste and preference of men and women vary across environmental conditions, and they behave differently due to various socio-cultural constructs, which is a dependent factor of their perception of a place [25]. People identify objects based on their level of perception. Proper identification of virtual building models based on users' perception and their activities is important for experimental studies using virtual reality. The user perceives the virtual atmosphere while they immerse in virtual reality [26]. We argue that it is important to select, develop and validate virtual building models based on user's perceptions in a social context. The selected virtual stimulus will aid experimental psychologists in studying perception, spatial memory, and virtual navigation. The virtual objects were chosen for their identification characteristics, level of comfort attached to it, sex dominance, facilities for sit, and sociability factors. The study's findings suggest that the virtual 3D building models may support future studies in various spatial navigation in small and large-scale environments.

6 Limitations of the Study

There are some drawbacks to the experimental methods applied in this study. The study was conducted amidst the pandemic situation of COVID 19. As per COVID protocols, including social distancing and lock-down, we were forced to adopt an online data collection method. As a result, participation is only from someone compatible with a computer or a modern cell phone with an internet facility, chances of excessive scores, the risk of bogus response, and lack of clarity of the respondents' uncertainty. Moreover, the sample is skewed and has more male participants than females (59.61% male participation). Nevertheless, the study does not address all the factors about sociability and quality of a 3D virtual representation in survey questions. We limited the survey to 5 critical factors (visual perception or identification of virtual models, level of comfort, sex dominance, the possibility for sit, and sociability factors). Future studies may incorporate other factors such as accessibility, connectivity, the public image of a place, with how people experience the buildings related to its environment to select 3d building models. It would be more appropriate if researchers compose and model their customized models for their research pursuits. However, in this study, we haven't explored cultural bias attached to the stimuli; hence, it is a potential limitation. A relatively small number of images of building models were used in this survey, and a larger number of 3D virtual building models may be developed and validated in further research.

7 Conclusion

To conclude, we observed essential social qualities related to the virtual models of significant architecture (i.e., level of comfort, sex difference, the place to sit, and the sociability of the site). Our findings suggest that sex differences might be one of the contributing factors in the preference of 3D virtual building models presented as 2D images. However, we believe that the 3D virtual models for socio-psychological studies such as virtual spatial navigation need to be examined from multiple scales of socio-psychological perspectives. The 3D building models can be adapted in size, color, texture, and visual complexity to fit the purposes of individual studies and applications. Some slight variations in a physical feature like color could change the perception of the objects. It would be fruitful for further researchers to modify building models' visual features in different contexts to study the relationship between color and structural significance related to 3D virtual building models. The 3-D building models can be used further for educational purposes and testing virtual-navigation protocols in 3-D virtual environments.

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Bucky—The Study of an Ergonomic Design Intervention for a Bucket Carrying Task

Sudip Ray, Tanmayee Puntambekar, Samantha Dimal, Shivangee Tilak, and Swasti Gautam

Abstract Carrying a bucket of water is one of the most common yet strenuous tasks performed on a daily basis. This manual handling exposes the user to awkward postures; repetitive movements in turn causing Musculoskeletal disorders (MSD); repetitive strain injuries & cumulative trauma disorders. This manual task also hinders the range of motion, reducing the efficiency, increasing the time and energy of the user. This research deals with the evaluation of the task through ergonomic assessments used to gauge posture and provide solutions to the problems in the form of a newly designed product. An experiment was created to assess manual handling through ergonomic assessments where data was collected through Observation methods, Videos, Photographs and Questionnaires to assess the task. Ergonomics Assessments-RULA (Rapid Upper Limb Assessment); REBA (Rapid Entire Body Assessment); OMPQ (Orebro Musculoskeletal Pain) questionnaires were conducted to assess the risk factors. The experiment showed that such a simple task was demanding as the scores from RULA and REBA majorly belonged to the 'very high risk' category. Utilizing the concepts of the lever system and hydraulics, the purpose of this study was to design an ergonomic 4-wheel trolley, equipped with a bracket and adjustable handle to overcome obstacles, improving efficiency and occupational safety, reducing the risk of slipping and/or toppling and single-handedly safe transport of the bucket. The solution is to design a product to ease the work and improve the safety and ease of the task by ensuring a better posture.

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Keywords Physical ergonomics · Musculoskeletal disorders · Repetitive strain injuries · Efficiency · Safety

1 Introduction

In our day-to-day lives, we all perform various tasks which are either strenuous for our bodies or make us susceptible to physical risks if performed repeatedly or over long periods, leading to fatigue and injury. Fatigue and micro-injuries have several occupational and non-occupational causes leading to a reduction in the quality of life [1]. Carrying a bucket of water is a classic example. Frequently carrying a heavy bucket is a demanding task creating a potential for injury. Most of the buckets observed include handles fixed at the center; hence the distance between the arm and the body increases when it contains water. This causes the user carrying the bucket to perform an arduous task. When water infrastructure is inadequate, the human body becomes part of the water delivery service [2]. Understanding the health impacts caused by exposing ourselves to physical conditions such as force, awkward postures, and repetitive motions that can potentially lead to physical injuries becomes crucial to avoid risk factors [3]. The main risk factors associated with the development of injuries are Awkward postures such as bending done while lifting the bucket, Forceful movement done while lifting the bucket, Pressure points where the bucket is grasp [4]. Even though the task of carrying a bucket of water is simple and does not include too many complex steps, as an activity, it causes severe internal injuries to the muscles and bones of a person performing the task regularly. The regular practice of carrying the buckets of water adds the physical loading with the potential risk of musculoskeletal disorders (MSD) and related disabilities by constantly exercising this activity, we expose ourselves to physical conditions leading to the injuries, wasted energy and time. To circumvent the problems, we improve the fit between the task to be performed and our ability to perform the task [4].

The manual handling of a bucket of water exposed users to instant shocks to the body from the load, hindering their mobility, causing injuries, wasting resources, and exposing them to various physical complications. The repeated and constant exposure to these factors eventually leads to fatigue, discomfort, and over time causing people to suffer musculoskeletal disorders or MSDs. Some concerns regarding the manual handling of a bucket of water using existing conventional methods have appeared to expose users to physical complications such as instant shocks from the load, hindering their mobility, causing injuries, wasting time and energy. Hence, a task that imposes risk on our bodies must be simplified, and a solution must be brought up to reduce such risks of musculoskeletal disorders on the body. The task of carrying a bucket of water is carried out in various situations. It can be in situations like carrying a bucket of water from the location of the source to:—the area of parking for cleaning vehicles, the area of watering plants (garden) or Simple transfer to another location, etc.

Adults, housekeeping, Cleaners/ janitors, etc., are mostly found performing the task of transporting water in a bucket. The risk of injuries to their body exists in such situations. Transferring water was mainly performed by people carrying buckets (mean container weight 25 kg) over a certain distance. The prevalence of spinal (neck or back) pain was 69%, and back pain was 38% [5]. Throughout the study, parameters like holding posture, bucket weight, gripping force, and lifting height were considered. The aim was to configure a trolley/lifter to improve efficiency and occupational safety.

The paper also focuses on designing the product is equipped with proper grips, wheels for ease of movement, and a pedal that ensures that the user does not have to bend over to carry a heavy bucket causing a multitude of issues.

2 Literature Review

According to epidemiological studies by WHO, manual material handling tasks contribute to a hefty 90% of occupation-specific and 20% of community-based musculoskeletal disorders reported in India [6]. Manual material handling is associated and has been linked with musculoskeletal disorders and severe injuries. It has been proven that effective ergonomic interventions/techniques lower the physical demands of manual material handling, thereby reducing the frequency and severity of the musculoskeletal injuries [7]. In scenarios where women and children fetch water from a faraway place, the bucket or rather, pots, are usually carried with one hand near the waist of a woman and placed on the top of their heads while maintaining balance. Also, people in rural areas carry buckets of water while balancing and hanging them on two sides of a rod/ thick stick on their shoulders. According to World Health Organization (WHO), it is estimated that 40% of people over the age of 60 years suffer from MSD due to heavy lifting, bending and about 80% of the people have had low back pain at some point in their life [6]. Currently, there are quite a few alternatives accessible in the market to people; Cylinder-stand with wheels, a Platform trolley, and a Bucket cart are few options available to them.

Manual material handling while performing tasks like washing a car, watering plants is associated with musculoskeletal disorders (MSDs) and injuries such as strains and sprains to the lower back, shoulders, and upper limbs. Lifting heavy weights has been considered as one of the most notable causes of micro and macro injuries in the workplace. In fact, in 2001, the Bureau of Labor Statistics reported almost 36% of workplace injuries required absence and leaves of employees due to shoulder and back injuries [8]. The four main areas to which injuries are caused are:

i. Muscles injuries tend to happen while lifting heavy objects and damage muscles and connective tissue.
ii. While lifting weights, spines endure most of the weight hence going under immense pressure.

iii. Hand positioning is another critical aspect of lifting weights; doing it wrong will lead to sprained wrists and a broken wrist.
iv. Shoulder injuries mostly tend to transpire when people shift loads onto one arm or shoulder. This, in turn, can put much strain on the joint carrying most of the weight, that is, the shoulder [8].

At present, people are hesitant to switch to a better alternative due to the convenience, ease, and familiarity with which they can use or implement traditional methods. Housekeepers, parents, siblings, and staff are the critical focus groups for this mission. They have been performing this task for a very long time and do not pay much attention to how a task, as simple as this, can affect their bodies, even though they feel quite a lot of strain while performing it. Scientific evidence proved that the ergonomic intervention can be effective in lowering the physical demands of manual handling, in-turn reducing the occurrence and severity of the musculoskeletal injuries they can cause [9]. Utilizing the suitable equipment's in the workplace reduces the medical expenses of the workers and increase the efficiency of the company. When transporting heavy loads, the use of trolleys can pose a safety risk, especially in areas where transporting materials is complicated, such as elevated or inclined surfaces and stairs. Given this situation, the goal was to create an ergonomic trolley that would allow users to move heavy loads of up to 25 kg without being exposed to musculoskeletal disorders or accidents, especially in dangerous areas like rugged surfaces, elevated planes, and staircases.

3 Methodology

The data for the study was gathered using a combination of qualitative and quantitative approaches. To determine the risks for musculoskeletal disorders and injuries in a manual material handling task such as transporting a bucket of water, RULA and REBA assessments were primarily used. In addition to that, VAS and OMP assessments were also performed. The data collected was statistically analyzed.

RULA (Rapid Upper Limb Assessment) and REBA (Rapid Entire Body Assessment) are postural risk assessments designed to help assess the critical risks in manual pushing, pulling, and lifting operations involving the upper limb or the whole body's effort. Other ergonomics principles such as VAS (Visual analogue scale), a psychometric response scale used to measure pain. OMP (Orebro Musculoskeletal Pain) Questionnaire, a screening tool predicting long-term disability and failure to perform some tasks and anthropometry to identify the physical dimensions of the potential product were applied. Since occupational hazards were taken into account, the consideration of these assessments becomes crucial. Below are the various approaches that were used:

The REBA assessment was made in suitable scenarios. These scenarios needed to focus on the entire body posture of the subject performing the task [10]. People in those scenarios either just lifted the bucket of water or were almost putting the

bucket down on the floor; the bucket was not touching the ground. Hence, in such scenarios, the entire body required analysis. Parts like the neck, trunk, wrist, arms and legs were all under strain and at risk. The REBA score denoted the severity of disorders like MSDs and the urgency to investigate and implement changes in how the task was performed.

The scenarios suitable for performing a RULA assessment required attention to be paid to the upper limbs of the subject's body. Arms, wrist, trunk and neck were at higher risk than legs in such situations [11]. People in such scenarios were analysed when they were about to lift the bucket by gripping the bucket's handle; the bucket was on the ground. Hence, there was comparatively less pressure or strain on their legs than the upper part of the body. Like the REBA score, the RULA score also denoted the risk on the upper limbs and the need to implement changes in how the task is performed.

The VAS or Visual Analog Scale is a subjective measuring tool that can help us know more about acute or chronic pain suffered by people [12]. The person performing the assessment asks the subject about his or her pain and rates the pain experienced on a scale of 1 (no pain) to 10 (unbearable pain). It also includes a 'face' pain rating scale, which is supposed to be rated by the observer by assessing the subject's face when he or she is performing the task. The 'face' pain scale measures from 1 (no hurt) to 5 (hurts the worst).

OMP or Questionnaire is another tool that consists of various questions that include selecting one answer among a list of options and rating on a given scale (usually, these scales are from 1 to 10) [13]. This questionnaire helps determine where and how much the user felt pain, for how long, in what frequency and the attitude of the user towards the pain.

Experiment design:
Before conducting the experiment ethical clearance was taken from Research committee of Symbiosis Institute of Design before starting the experiment. The experiment was conducted among a group of 105 people. All the participants were asked to give the consent for the experiment. The participants were all Indians and ranged from an age group of 15–55. Here, 28% belonged to the age group of 15–25, 54% belonged to the age group of 25–45 and 18% to the 45 and above age group. There were 61 female and 44 male participants taking part in this experiment out of which 74% were employed and 26% were studying/unemployed. Participants were instructed to fill a bucket with water at one location and carry it to another place on the same floor. The duration and frequency of sustaining a posture are the critical parameters to define a working posture risky as sustaining an unsuitable posture for a very short duration but on a regular basis potentially poses risk. For the experiment, the duration of the task was averaged at 48 s performed indoors with an average distance of 13.5 m. As the task was being performed, and were documented. Images and videos of the participants were also taken. The same was subjected to RULA or REBA assessments while considering human anthropometric measurements. Other ergonomic assessments include- VAS, an ergonomic evaluation used to rate the pain experienced, and an OMP questionnaire (filled out by those who performed the task

regularly). The task of transporting water in a bucket was constructed to fulfil the Intervention Development requirements, which are divided into three sub-tasks:

i. Filling and lifting the bucket of water
ii. Carrying the bucket to the desired location and
iii. Transferring the content of the bucket at the location

The task and questionnaire were designed so that the key risks associated with manual pushing and lifting operations that require whole-body action, such as shifting filled buckets, could be accessed, analyzed, and evaluated. It assisted us in determining high-risk pulling and lifting practices and evaluated the feasibility of some risk-reduction strategies. The conduction of the task was structured in such a way that the following constraints were fulfilled-

i. Performed by only one person at a time
ii. Feasibility requirements
iii. Performed indoors (the bucket was transported from one location to another on the same floor), e.g., from the washroom to a different place.
iv. Load standardization and consistency; should be around 25 kg.

On the basses of the analyses achieved by the experiment. The Design process of Creating a trolley was done improve efficiency and occupational safety.

4 Results and Discussion

The data collected was analyzed statistically to derive the conclusion. All the figures were analyses statistically to compare the joint pain and the assessed score. The task assessments revealed that an ergonomic and effective/efficient supporting tool for manual bucket handling is needed. All participants attributed their discomfort and pain to a specific activity of manual handling of the bucket of water task as the critical source. Both participant's primary work-related stress and pain or injury are mainly based on their spine (29%), wrist (29%) and shoulder (25%) areas, with elbow (13%) and wrist (4%) being the least according to findings from interviews and assessments (Figs. 1 and 2).

The results of the experiment were entirely on the severe side. Results of RULA assessments showed a majority (58%) in the score '5 to 6', which would mean that the methods used to perform the task needed further investigation. A change was necessary to remove the risk factors (Fig. 3).

REBA assessments landed on results that showed the need for immediate changes as the person performing the task was at a very high risk, which was denoted by the majority (58%) score of '11 and above (Fig. 4).

The OMP- risk factors mentioned that only 25% people are at low risk and does not need immediate intervention. Whereas the 29% of people are at Medium risk and 46% of people are at High Risk. These might need immediate intervention.

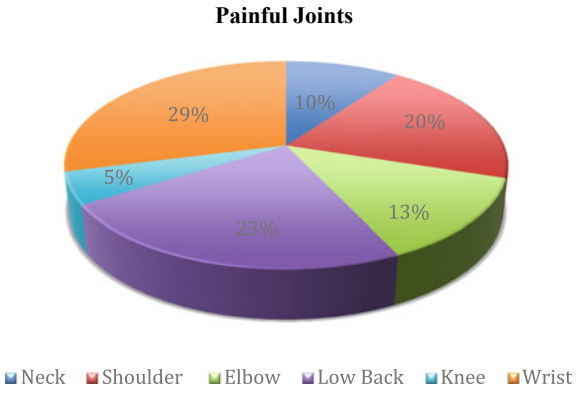

Fig. 1 Pie chart showing joints/affected the most while performing the task

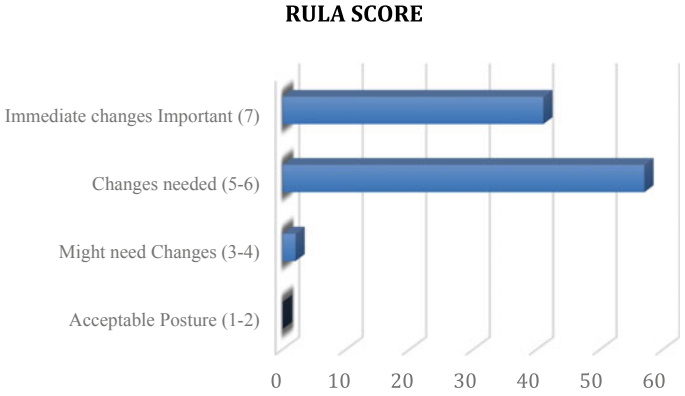

Fig. 2 RULA scores after assessment

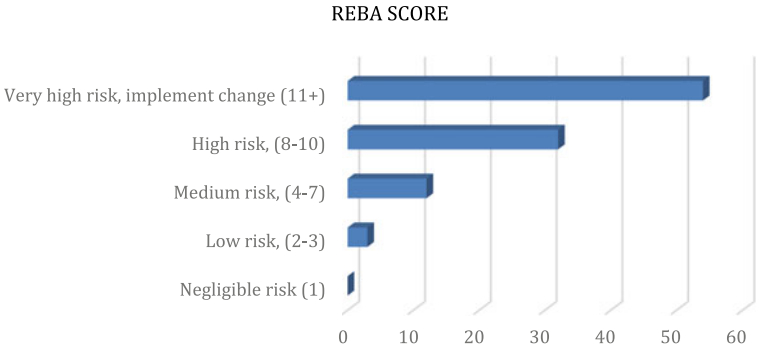

Fig. 3 Pie chart showing REBA scores after assessment

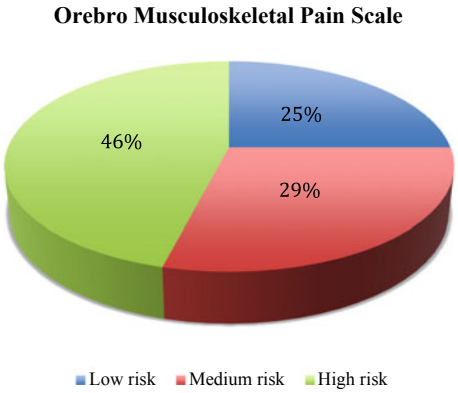

Fig. 4 Pie chart showing OMP-risks

The findings of this study revealed that subjects have discomfort and problems while doing the task particularly. An innovation needs to be developed which can be effective in reducing the pain and discomfort caused. The developed product could be effective in reducing the overall MSD risk associated with bucket handling. This approach is might anticipate the reduction in the overall MSD risk since it fixates on the strength of the new design reducing the risk factors. This approach is expected to be effective if the job requires the bucket to be carried over the required distance. The task of moving water entails filling a bucket with water, lifting it and holding a large load using the bucket's handle; this causes strain to the body. As a result, a solution that would help reduce/minimize the stress and risk while still increasing the ease of performing the job in a limited amount of time is required.

Bucky- Is the design intervention consisting of a 4-wheel trolley that can carry a load of 25-kg weight. It has a rotating handle (With a non-slip grip knob with grooves on the sides, the angle can be changed and adjusted) to alleviate pain caused by physical differences in the user (e.g., height), allowing it to be adaptable and flexible to the user and efficiently transporting load single-handedly. The force of the holding and lifting load is transferred to the pulling and pushing of the load. The trolley operates on a lever mechanism, which means that the user applies less tension to the pedal. The effect generated by the trolley to lift the bucket is more excellent and more comfortable. The hydraulic system aids the user in pushing the pedal with ease, comfort and efficiency. Overall, the trolley's design focuses on making the task effective for the user not only when conducting the task, but also after the task is completed and when it comes to comfortably storing the trolley. The 4 Tier Trolley with retractable wheels also opens and folds flat in seconds for compact storage. The simple and easy storage quality folding makes it easier to stack the trolley without utilizing too much space. This also makes carrying the stacked trolley convenient for the user (Fig. 5).

Furthermore, the ergonomic trolley was designed using anthropometric criteria such as handbreadth with the thumb, foot length, handgrip diameter, and so on to adapt

Fig. 5 BUCKY

the trolley's configuration to the user's anthropometric requirements. The essential criteria applied during the process of design selections were:

i. The design was made simple to understand and use. Complicated mechanisms, such as electrical/mechanical powered instruments, were avoided.
ii. The design might reduce the risk at the joint but not surely add the risks at other joints such as shoulder, arms, wrists, etc.

The study's key emphasis was on the design and any improvements in design that may minimize the risk variables. The results of the manual handling of the bucket highlighted the need to develop interventions to address jobs that place users performing the task at increased risk of MSDs, including bucket handling.

5 Limitations and Future Scope

The experiment was conducted prior to the Covid-19 outbreak, thus data collection and analysis were feasible, but the trolley design was implemented during the pandemic. Hence, the testing and prototype could not be completely accomplished, leaving us with no comparison between pre and post-data. Due to time constraints, the primary focus was on functionality rather than aesthetics. The ergonomic trolley was intended to use data from a variety of sources, including theories, operating principles, and ergonomic examinations. Considering the limitations of the assessments and experiments, it left us with a scope of improvement and refinement in the design in terms of function and aesthetics. Besides this, we can even look into making this product on a larger scale moving from indoors to outdoors. With that in mind and a variety of other factors, our next objective is to revisit 105 participants, review,

reassess and retest the design while the task is performed using the prototype. Our future scope aims to create an improved, enhanced and functional design that incorporates user feedback from the testing stage and addresses the issue more efficiently than ever.

6 Conclusion

This study aimed to implement and assess the efficacy of a newly developed intervention in reducing MSD risks associated with bucket handling tasks. This study designed and built a non-motorized trolley based on end-user input from the assessments. The new design, designed ergonomically using anthropometric measurements for a standard bucket and trolley, promises to improve work efficiency, occupational safety, and health conditions. The developed trolley is well equipped with proper grips, wheels for ease of movement, and a pedal mechanism that ensures that the user does not have to bend over and carry a heavy bucket which causes risks for their bodies and allows for a better working posture (apparent reduction in RULA and REBA score ratings in certain task process segments) for transferring a bucket of water and eliminates the need to provide manual contact/support to the heavy bucket throughout the transfer process. Compared to manual bucket handling, the established interventions significantly reduced MSD risks, especially during the carrying and dumping of a bucket of water. The design solution does neither increase nor introduce any strain or risk to the body parts besides the lower back (e.g., shoulder, arms, wrists, etc.) and aims to reduce them to the extent of making the task less strenuous to an individual's body. An approach that incorporates lifting, carrying, and dumping with ease resulted in the lowest MSD risk during bucket handling by users, especially when carrying buckets over a long period.

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Why Does an Indian Construction Worker Fail to Wear Personal Protective Equipment (PPE) at Workplace?

C. Vigneshkumar and Urmi Ravindra Salve

Abstract Personal protective equipment (PPE) is an essential control measure used in developing countries to protect workers from hazards and risks in the construction industry. The purpose of PPE is to reduce workers' exposure to the environment. From the literature, it was noted that a worker not wearing the provided PPE or the absence of PPE at the workplace leads to the cause of accidents in construction every year. The purpose of this study is to examine why workers fail to wear PPE on Indian construction sites. A structured questionnaire-based study was carried out among workers of the construction industry to collect data. The factors that influence the workers not to wear PPE in the workplace were analyzed and represented graphically under the following three sections (i) design-related aspects; (ii) management-related factors; and (iii) human-related factors based on the workers' job and their age group. This study revealed that most workers understand the importance of PPE and want them to protect themselves from accidents/injuries. However, there is a need to address the issue concerning PPE on construction sites. This study's outcome can be used for effective use of PPE among all workers at the Indian construction site and enhance health and safety. Further involvement in promoting the use of PPE should be focused on the availability of PPE, job duration, and presence of shift work.

Keywords Construction safety · PPE · Construction industry · Workers safety · Behaviour · India

1 Introduction

Industrial safety helmets are often used as personal protective equipment (PPE) [1]. These helmets protect the head against falling objects, lateral forces, high temperature, electrical shock, hitting permanent unsafe objects, and so on [2]. Workers use safety helmets to guard them against injuries when associated with cranes, hoists, etc.

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[3]. But due to its less comfort level, safety helmets are often neglected in construction workplaces in many cases [1]. This leads to one of the causes of fatal accidents in the construction industry [1].

According to (HSE 2015), six workers in UK construction were died due to falling or flying objects and being hit by moving objects [2]. This is because of not wearing safety helmets at construction workplaces. Head injuries accounted not only for fatalities but also affected the brain function of a human. Minor head injuries lead to dizziness, depression, headaches, and irritability, fatigue, and memory problems [3]. Usually, workers are not ready to wear safety helmets in construction workplaces. The performance in the impact of safety helmets has been examined in previous studies for different countries to enhance user acceptability [5]. However, due to its discomfort, many workers are not willing to wear [1].

The same has been followed in India, where construction workers are not ready to wear safety helmets during their work at the workplace. Although the description of safety helmet features is available in the Bureau of Indian Standards (BIS), there are various comfortability issues among Indian construction workers while using safety helmets. Therefore, an aim was set to investigate various causes of discomfort while using safety helmets by Indian construction workers. In this study, the discomfort of the safety helmet was evaluated in terms of comfort, heaviness, fitness, and hotness. Also, awareness of using safety helmets at construction workplaces was also evaluated among workers. The result shows a much need for redesigning existing helmets to make them comfortable for Indian construction workers.

2 Methodology

2.1 Pilot Study

A literature review was carried out to understand various features which may cause discomfort while using a safety helmet at a construction workplace. The features of safety helmets were taken from [4]. The study consists of subjective investigations at construction workplaces of Guwahati city. Two construction workplaces from the Indian Institute of Technology Guwahati (IITG) were selected.

From the Bureau of Indian standard (BIS) and literature, it was observed that fitness (proper fitment), comfort, hotness, and heaviness are the four mandatory criteria to be incorporated in helmet design [4]. Therefore, four criteria such as fitness, easiness to view, hotness, and heaviness were selected to evaluate the existing helmet used in the Indian construction industry. Randomly four male workers were selected to assess the current safety helmet. The questions asked to workers were related to fitness (proper fitment), ease of view, hotness, and heaviness of safety helmets.

2.2 Onsite Observations and Problem Identification

The problem in safety helmets was observed through general discussion with construction workers at the workplace. The workers who participated in the general discussion were bar benders, brick workers, plastering workers, and form workers. It was observed that no proper vision, fewer grips to keep the safety helmet fit with the head, lack of ventilation, sweating, and itching were the primary reasons for discomfort while wearing an existing safety helmet.

2.3 Question Formation and Data Collection

Once the problems were observed from construction workers, a set of questions was prepared to collect data related to a safety helmet. The question contains the general characteristics of respondents and the comfort level of existing safety helmets at construction workplaces. Workers who were actively associated with the construction activities such as beam shuttering, bar bending, plastering, brickwork, and carpentering possessing sufficient experience in the industry participated in this questionnaire survey. These workers were selected because they were actively involved in the ongoing projects. The survey took place over two months and lasted approximately 1 h. A total of 36 participants were responded to the study, and the majority of their age group falls between 21 and 30. The respondents were asked to give their opinion regarding the existing safety helmet.

3 Results

3.1 Respondents' Characteristics

In this survey, 36 male respondents have participated. Table 1 shows the characteristics of respondents who participated in the survey. It can be seen that the maximum number of respondents (21 responses) had an age group of 21 to 25. Attendees' span of experience in the industry revealed that 18 responses (50%) had between 1 to 4 years of experience, and 8% had less than one year in construction. Almost 31% of respondents' nature of the job was beam shuttering followed by bar bending (22%) and plastering (22%). Six responses (17%) were brick workers, and the remaining 8% were carpenters. The duration of work of each worker per day and week is also shown in Table 1.

Table 1 Characteristics of the respondents

Characteristics		Respondents	
		N	%
Age group (in yrs)	< 20	6	17
	21–25	21	58
	25–30	9	25
	> 30	0	0
Experience in construction (in yrs)	< 1	3	8
	2–4	18	50
	4–8	12	34
	> 8	3	8
Type of work	Beam shuttering	11	31
	Brick work	6	17
	Carpentering	3	8
	Bar bending	8	22
	Hacking work (plastering)	8	22
Duration of work in hrs/day	< 6	9	25
	7–8	27	75
	>8	0	0
Duration of work in days/week	<5	0	0
	5–6	6	17
	>6	30	83

3.2 Awareness of Safety Helmet Among Worker

The respondents were asked about their awareness of using safety helmets during work at the worksite. All 36 participants aware that helmet is for their safety. Further, the respondents were asked why they were not wearing a safety helmet at the workplace. All 36 responses reacted that they were not comfortable using existing safety helmets at the construction workplace. The reasons for the discomfort of safety helmets are discussed in the next section.

3.3 Reasons for Discomfort in Using an Existing Safety Helmet

Respondents were asked about the discomfort of the existing safety helmet. Results were presented in Fig. 1. Almost 25% of respondents react that they have a problem in viewing, followed by 22% of respondents react that combined hotness, sweating, and itching are the significant problems for discomfort. 14% responded that they

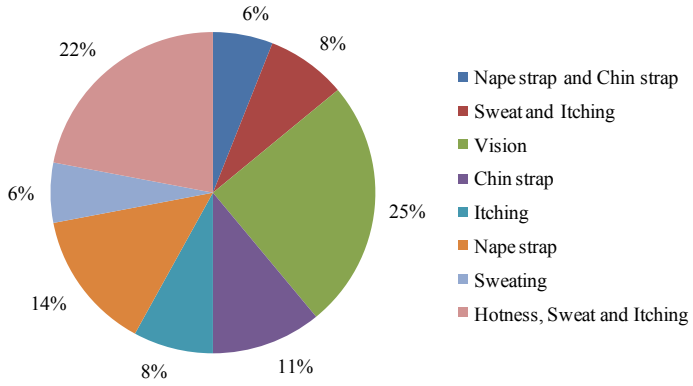

Fig. 1 Reasons for discomfort in existing safety helmet

felt discomfort with the nape strap, followed by 11% of respondents react that they felt discomfort with the chin strap. Subsequently, 8% of respondents react that both sweating and itching were the problems and another 8% of respondents react that only itching was the major problem for their discomfort. Followed by 6% of respondents react that only sweating was the problem, and on another side, another 6% of the respondents respond that both nape strap and chin strap were major problems for their discomfort.

4 Discussion

Comfort is one of the critical parameters that have to be compromised while manufacturing and using a safety helmet. There is no use in providing helmets to workers without considering wearability needs, thereby demotivating workers to use them [5]. However, there must be a minor element of unavoidable discomfort in any protective wear, where workers must adjust [1]. According to John et al. [1], discomfort in safety helmets can be attained by long-term and continuous use of safety helmets that are initially uncomfortable.

This study in northeastern India revealed that the workers were well aware of using safety helmets in the workplace. But the helmets provided for them were not comfortable to use. In tropical countries, hotness is the major complaint among helmet users [1]. Sweating and itching are some of the reasons because of hotness. Here, respondents react that they were feeling discomfort because of sweating and itching due to the hotness of helmets.

On the other hand, discomfort due to vision accounts for 25%. Nape strap and chin strap are the elements provided to fit the helmet on the skull of the human body [1]. It has been noted here that nape strap and chin strap contribute a higher percentage in discomfort to workers for not using safety helmets.

The responsibility of each employer is to provide comfortable safety helmets to workers at the workplace. Therefore, an employer needs to choose the correct type of safety helmets that protect workers from hazards and be comfortable for them to wear. The comfort level of safety helmets can be improved by selecting appropriate elements associated with them. For example, lightweight material for the helmet shell, a flexible headband to fit the forehead, a sweatband that is easy to replace or clean, a textile cradle strap, etc., could avoid discomfort to workers while working. Fitness can be ensured by the right shell size of the helmet, which should not affect the viewing angle of the workers, and an easily adjustable chin strap, head strap, and headband. To improve the safety performance of safety helmets, statutory specification requirements should be amended so that there is an approved list of standards from which employers can select safety helmets for their employees [6].

Moreover, the specification provided in BIS for safety helmets will not be much sufficient to manufacture a comfortable helmet for workers. It has shown only an overview of safety helmets and a simple drawing which could not give a complete detail of helmet elements. Keeping the sizes provided in BIS, all other features can be referred from different countries' standards like American National Standard- ANSI Z89.1, Canadian Standard- CSA Z94.1, European Standard EN397, etc.

5 Conclusion

This study investigated why Indian construction workers fail to wear safety helmets during work at the worksite. A set of questions were prepared based on workplace observations, pilot study, and literature review. The study aimed to determine the comfort level of existing safety helmets at workplaces. Thirty-six workers actively participated in this study. The analysis revealed that discomfort was the critical factor influencing workers not to wear a safety helmet at the workplace. Reasons for the discomfort of safety helmets were evaluated in terms of comfort, heaviness, fitness, and hotness. The results show that the workers who participated in this survey had an awareness of why to use safety helmets. But, because of less comfort level, they are not ready to wear it. It can understand that if the helmet is comfortable for them to use, they may use it properly. Hence, I strongly recommend that there is a need to redesign existing helmets available in construction industries. This study was limited to northeastern part of India, and much more studies have to be carried out all over the regions of India. Also, construction workers from different activities should be considered in future to cover a wider range of issues in safety helmets. So a proper understanding of the existing situation in using safety helmets can be understood, and new features can be recommended for updating BIS, which can motivate the workers to wear helmets at the workplace.

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To Explore an Innovative Process to Offer Personalized Learning by Providing Localized Accessibility for Both Teachers and Students with the Help of a Mobile Application

Himadri Saloi, Abhijit Padun, and Abhay Verma

Abstract In India, there exists a system of private or personalized learning at home in parallel to the regular academic classes offered at schools to overcome inadequacies in the learning process. The system is commonly termed tuition in India, which many school-going kids used to follow. Moreover, students who desire to excel in academics invariably also follow personalized coaching for their studies. Though various online coaching firms like Byju's, Vedantu, etc. are available nowadays, no such online platform is used to offer tutors who would offer service for both offline and online mode. Hence, an alternative tutoring platform may be desired that can address the limitations of personalized coaching by offering both offline and online modes with quality services. This study was particularly carried out to conceptualize such an online platform by creating an application for digital devices which may address the necessity of personalized coaching with exclusive offerings. The app concept has been designed to help students and their parents to search for tutors of different subjects and getting in touch with them physically and virtually both for personalized coaching. The app further explores connecting people of quality teaching capability from varied fields to a wide range of students from different places for knowledge exchange and learning. The primary focus has been put on content interactivity and smooth flow of information and navigation style for the users to make the application efficient and effective.

Keywords Personalized learning · Interactive learning app · Home Tuition · Personal Tutor · Home schooling · Personalized coaching app

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1 Introduction

The primary education in India in earlier period of time followed the conventional way of teaching which basically delivered education through recitation and memorization technique. The process involved the teaching using chalk and board for teachers and pen and paper for students. The teacher uses methods like demonstration using examples, lecture methods, question answer methods. This basic education method is still widely practiced throughout the globe over many years now. The students gained knowledge from the face-to-face interaction with the teacher and this system is still followed with the students now having the option to communicate from home to their respective educational Institutes/Universities [1]. The way in which conventional methods were taught ensure that students were rewarded for their efforts, used class periods efficiently and exercised clear rules to manage students behavior. But the conduct of education in this twenty-first century has been witnessed shifting from a face to face teaching environment to a more technology based learning environment. The new transformation in using mobile technology and social media provide new alternatives towards more dynamic learning environment [2]. The education process is more implemented with web based learning using various online platforms, e-learning apps and video channels.

The introduction to e-learning has provided the students with ample scope to search and acquire all the knowledge required. All the schools, colleges and other institutional organization are seen to embrace online education platforms. This way of learning improves students' academic progress. It helps to surpass the barrier of space and time and keep the teachers, students and parents virtually connected. Online education has experienced a great transformation with the advent of e-learning apps. E-learning apps have accumulated praise from parents and students from all over the world. The primary idea of such apps is that all the educational stuff that students study in their schools and tuition classrooms has been made available for students in their smartphones from the comforts of their homes. These apps provide top-notch methods to engage students in studying and most importantly making the studies interesting. Today many such popular apps are being used and accepted worldwide by both teachers and students. These apps present the content in a concise manner due to which learners can acquire and learn quickly. It also promotes collaborative learning through online communities within the app. Such apps also provide flexibility by providing various options of learning to the students in the form of podcasts, videos and other fruitful methods. Moreover parents have also been made a part of this structure as they are kept in touch regarding the performance of their child. One of the current trends of such apps is about gamifying the learning experience with the help of all sorts of innovation methods to make learning playful. Another aspect in these apps is to use trigger for motivation which will keep the students engaged in the process of learning. Moreover such apps are designed with uncluttered interfaces to keep the app light and simple by efficient use of space and clean layouts. Interactive content, easy to use and understand lessons makes the learning process fun which makes the learners retain info easily and stay on app longer. These e-learning apps

have helped for the growth of students and also taken the teachers into consideration. E-learning apps have come a lot handy in the pursuit of learning the new methods of teaching and learning altogether.

2 Background and Need Identification

In today's world of education, personalized tuition has become a necessary part of the system which helps the students struggling with their academics and also help enhancing and improving the overall performance of the students. Parents engage some tutors at home for the making up the academic deficiencies and for increasing the academic abilities of their children [3]. There are a lot of mobile applications and other online platforms present which provide personalized tuitions and classes. But no such applications are designed which provides option for offline classes. During conduction of classes in online mode various distractions may arise such as hardware and software issues. Kids may misuse the phone or easily get distraction during the online class. There is also no one to one interaction between the teacher and students because of the presence of large number of students due to which indiscipline and chaos might be created in the group. In remote places, lack of internet connectivity and electricity may also be a case of concern. Moreover such online courses are very expensive and unaffordable for many.

Students in many places still rely on private or personalized tuition where they can come in contact with the teachers available locally as well as with experts from other places. Parents usually become weary while searching for the best tutor for their child. An effort has been made to design a mobile application which will fulfil the gaps and limitations of all the available online platforms for education. The main aim is to design a mobile application which will provide classes for both online and offline mode according to the convenience of the teachers and students. In this app, the person who is willing to take tuitions can register with all the details and the students will be able to search for teachers for particular subjects based on the location provided. This app will improve the conventional way of personalized teaching and will provide a new way of connecting teachers to the students. It will also provide as a platform for employment generation for the teachers. Moreover people who are not very sound and not comfortable with technology but having a good teaching skill can be benefitted.

3 Literature Study

The education sector has seen a drastic change in its approach as more resources have been made available such as e-learning mobile apps. The basic idea of such apps is to make all the educational stuff available for students in their smartphones. Google Classroom, Zoom, Byju's, Unacademy, Vedantu are few of various available

online platforms which facilitates for conduction of online classes. But most of these applications are not affordable for many due to the high cost structure. The most common complaint about online learning is that it lacks face-to-face interaction and spontaneous exchange of ideas that one can only grab with classmates and a teacher in real time [4]. The conventional way of education provides active face to face interaction where extracurricular activities can also be performed alongside learning. The long term effects of exposure to the computer screen for long hours due to online classes is leading to certain vision problems in children [5]. Though many students see the online process of learning to be nearly as good but traditional instructions seems to be the best solution to give attention to the underachieving students. Conventional education has been around since forever and it seems like its numerous perks will make it impossible for it to be entirely replaced by any other learning format. Also students are quite dependent and rely on private or personalized tuition where they can come in direct contact with locally available teachers. But finding a perfect locally available tutor for the child becomes a tedious task for the parents. There are few applications such as UrbanPro, Teacheron etc. which help find tutors for the students but such apps fail to provide tutors from all localized area [6]. An effort has been made to design a mobile application which will bridge the gap and limitations of all the available online platform for tutoring.

4 Aim and Objectives

Aim

To design a mobile app which will provide facilities of personalized teaching in both online and offline mode with an innovative process where teachers and students both get benefitted.

Objectives

- Analyzing existing mobile apps providing personalized teaching.
- Observing the need and demand of end users who are students and teachers
- Conceptualizing a smooth and innovative workflow for both the end users to be applicable on mobile devices
- Designing a mobile app for to execute the innovative workflow with appealing user experience and interface.

5 Set up Methodology

A step by step methodology has been set up to conceive the aim and objectives of the experiment. Figure 1 shows a schematic diagram of the work flow of chosen methodology.

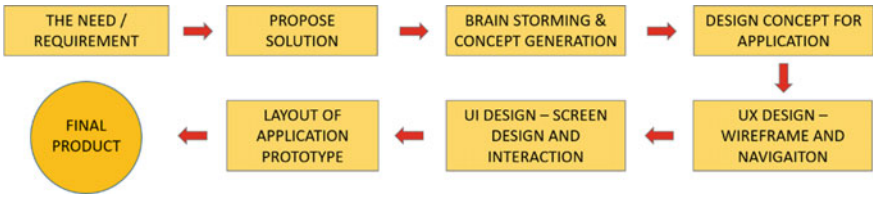

Fig. 1 Schematic view of chosen methodology

5.1 The Need/Requirement

The need and requirement found from the background study of various available platforms for conduction of online and offline classes for the purpose of tutoring has been as follows—Personalized tuition help students to achieve good results and to maintain balance between studies and recreation. Finding an excellent tutor who is knowledgeable in the subject becomes a tedious task for the parents. Moreover no platform is available for booking tutors for offline mode of conduct of tuition.

5.2 Proposed Solution

To overcome these major problems a mobile application has been designed to explore an innovative process to offer personalized learning by providing localized accessibility for both teachers and students. A digital platform has been designed which can efficiently connect students and teachers in a systematic approach to conceptualize a strategy which can work for both online and offline mode of learning.

5.3 Brainstorming and Concept Generation

The main brainstorming technique used while finalizing the concept is 'Individual brainstorming' which is basically used in solitary situations which includes techniques of free writing, free speaking, word association and drawing a mind map. Various directions were tried to come up with the proposed idea as shown in Fig. 2. At first target was to create a website where parents will be able to search for the tutor nearby for the specific subject of interest. Based on that he/she can establish the communication with the tutor and carry forward for the next step of registration. However this way of approaching was replaced by a mobile based application as mobile apps have the advantage of being faster and more efficient. The name of the app was finalized as "TUTORACT" which is the combination of two words 'TUTOR' and 'INTERACT'.

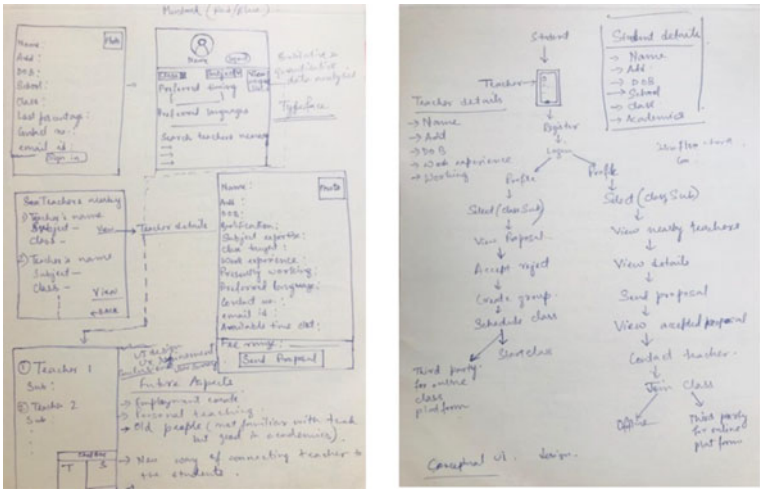

Fig. 2 Brainstorming and concept generation for the app

5.4 Design Concept for Application

A convenient mobile based application has been designed where tutors registered are made available to be found by the students for online/offline mode of conducting class as shown in Fig. 3. The students once registered can search for the appropriate tutor nearby for the desired subjects. The students can send tuition proposal to the selected tutors after viewing the detailed information regarding academics, subjects, fees, timing and venue. Below is the flow chart of work process on the app for students.

As shown in Fig. 4, the teacher once registered with all the details can view the proposal from various students for various subjects. On acceptance of the proposal by the tutor, both the parties will get virtually connected and can decide on conduction of classes based on their convenience. Below is the flow chart of work process on the app for teachers.

The information architecture of the overall flow of the application is shown in Fig. 5. The blue colour of the font represents the flow of the teacher and the red colour font represents that of the students.

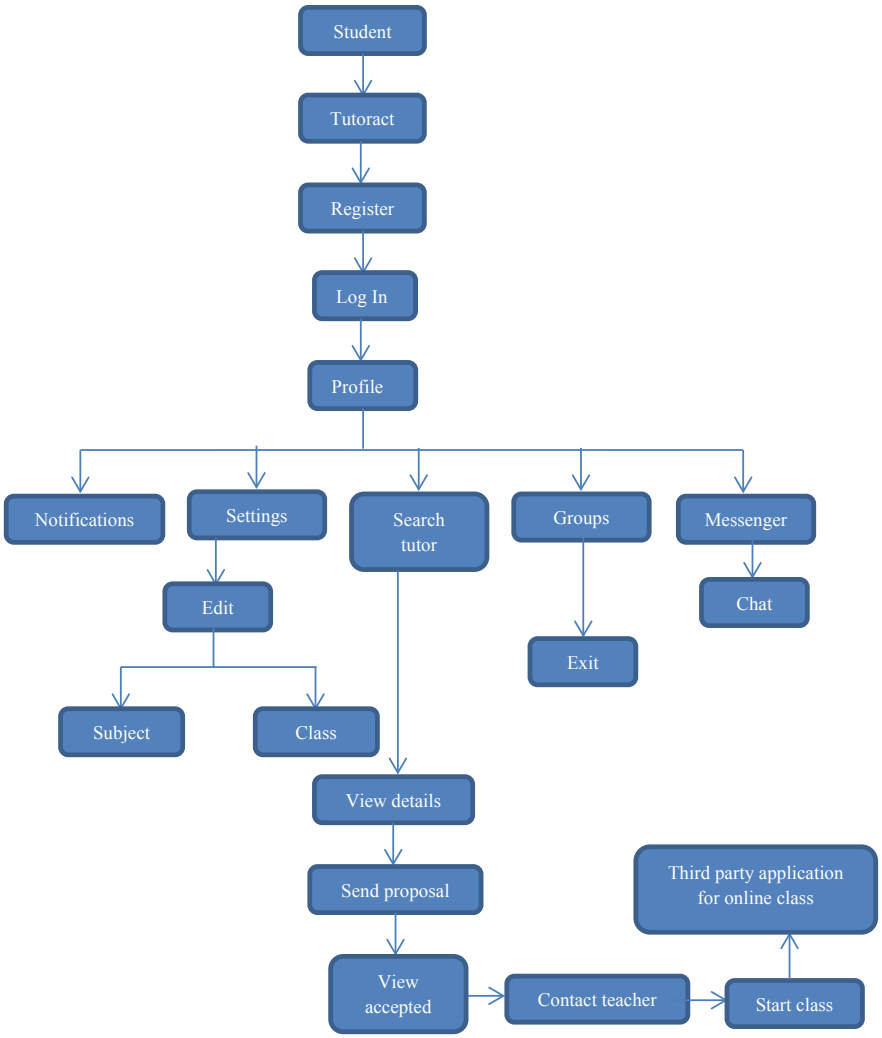

Fig. 3 App flow for the user (student)

5.5 UX Design—Wireframe and Navigation

An effort has been made to create an effective and user-friendly design to target the need of the users. During the process of creating the UX, focus has been made to have a deep understanding of users, what they need, what they value, their abilities and also their limitations. Few screen wireframes are shown here in Fig. 6.

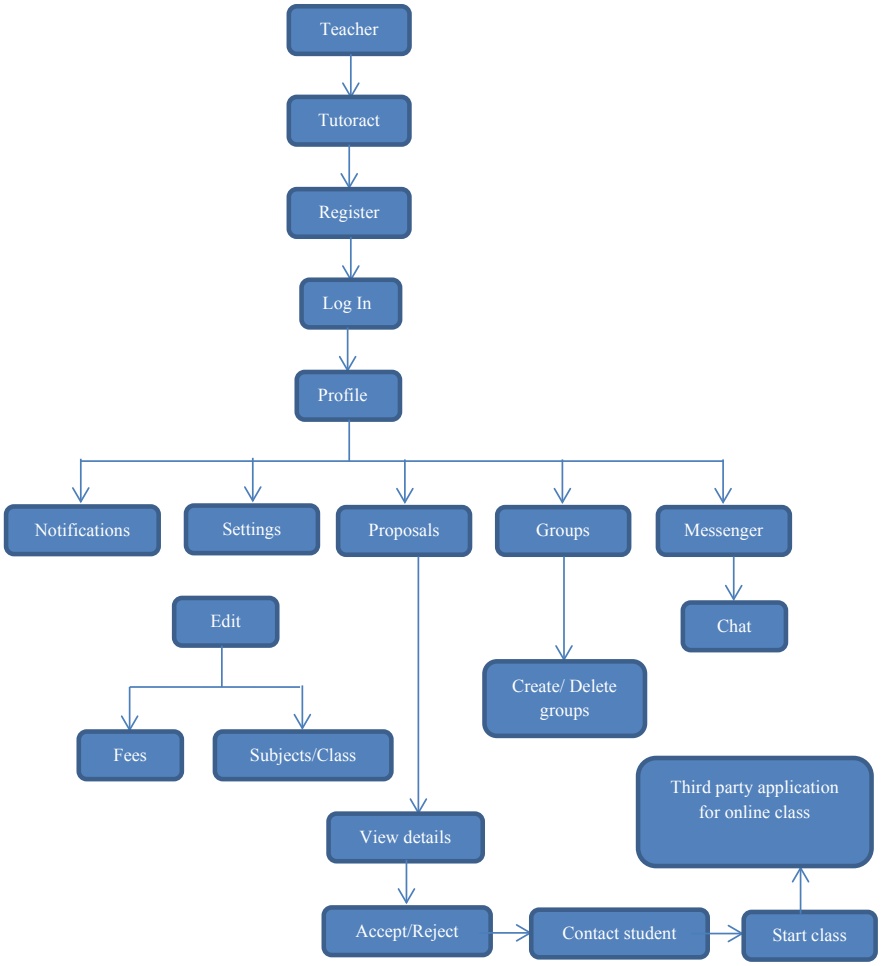

Fig. 4 App flow for the user (teacher)

5.6 UI Design—Screen Design and Interaction

An aim has been made to create simple interfaces to portray minimalistic design with sober and light colour scheme with focused contents to address and appeal users. The first conceptual design idea for User Interface in Adobe XD has been shown in Fig. 7. In this screen UI design dual colour palette (purple and white) and typeface "Roboto" has been used.

The first conceptual design has few limitations of its look and feel, navigation system, colour scheme etc. due to which a second alternative user interface has been designed. The second and final conceptual design idea for User Interface designed in Figma has been shown below in Fig. 8. The selected typeface for this design is

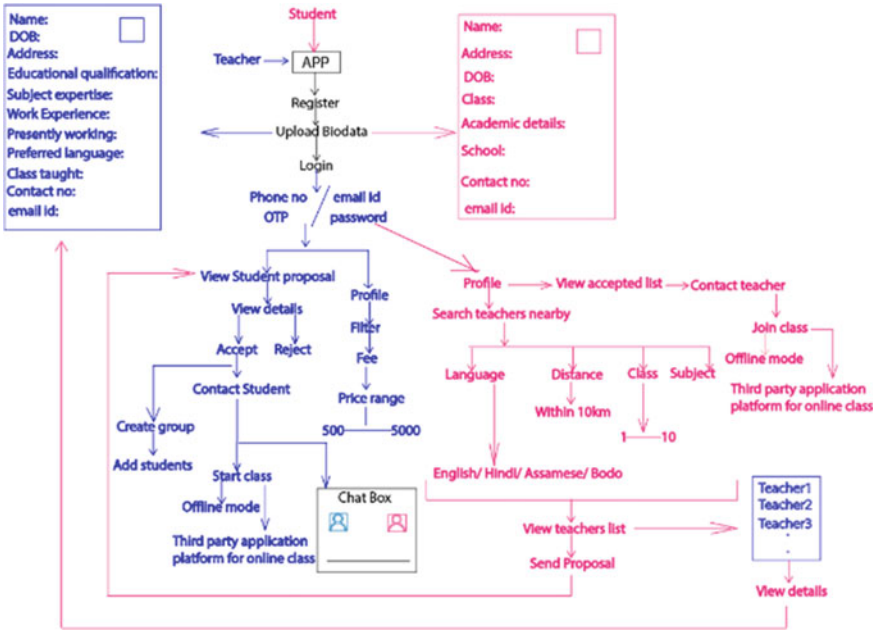

Fig. 5 Information architecture of the application

Fig. 6 User experience of the application TUTORACT

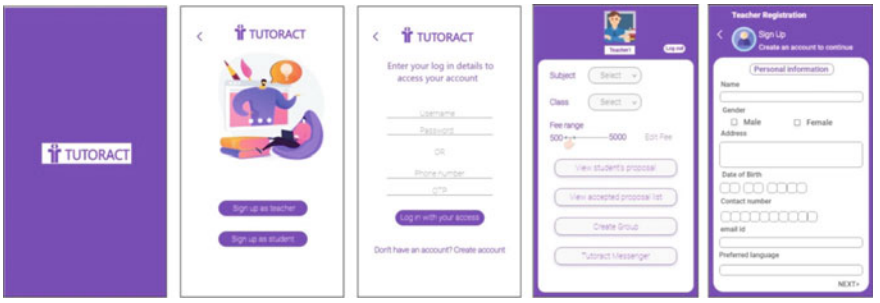

Fig. 7 Detection images of maize kernels of five different varieties

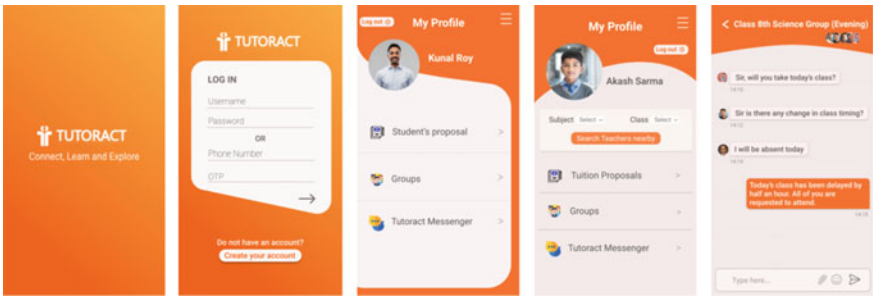

Fig. 8 User interface design-II of the application TUTORACT

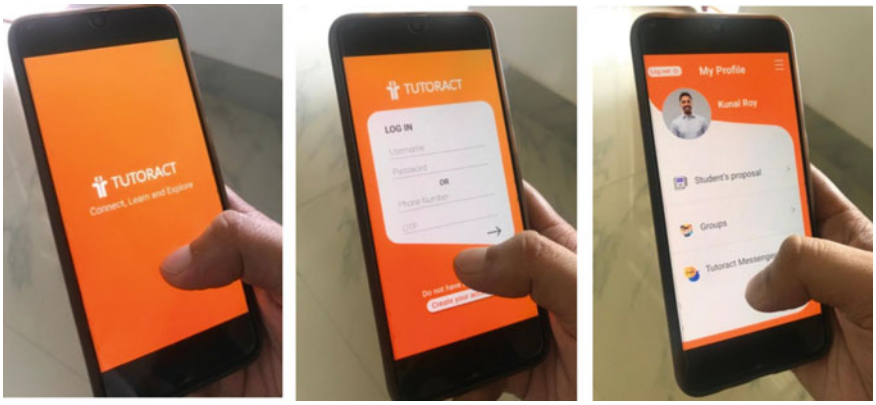

Fig. 9 Final prototype

'Roboto'.

5.7 Final Prototype

Prototypes help replicate how users might interact with the design. After creating the final prototype, it can be viewed on mobile devices as shown below in Fig. 9.

6 User Survey and Feedback

The initial design prototype was presented to a number of potential users and few feedbacks were received which included issues with the navigation system, colour scheme, buttons and illustrations, typography arrangements etc. Based on the feedbacks received, a new prototype was designed, filtering out the limitations and drawbacks of the initial design. After the development of the new prototype, the app has been presented to a group of prospective users consist of students from schools and their parents. A questionnaire has been set up to take the user feedback on its effectiveness, usability, appeal, achieving target etc. The main factors that have been highlighted during the survey are the need of the students and teachers for the purpose of tutoring. The employment generation ability of the application was also taken into consideration. The navigation system, user experience, user interaction and use of design element was also tested during the survey. A total of 24 offline and 30 online prospective users have been invited to participate for the user survey. After conduction of the total survey, the overall acceptability rate of users is 75.5%, which is above 50% and can be counted as above average rating and shows promising sign. The graphical representation of the user survey has been presented base on the following key factors of the application where participating users have evaluated the key factors on a score of 10 points.

- Factor 1: Student's need
- Factor 2: Teacher's need
- Factor 3: Employment generation ability
- Factor 4: Interactive nature
- Factor 5: Navigation system
- Factor 6: Appeal to user
- Factor 7: User experience
- Factor 8: Overall colour scheme and feel
- Factor 9: Use of design element
- Factor 10: Addressing local tuition need

Shown below is a graphical representation of factors and scores based on user survey (Fig. 10).

As seen in the graphical representation, the scores received by all the factors have been above 5 points and the acceptability rate of user is 75.5% which could be counted as above average rating and shows promising sign. Hence it can be said that the app concept has been able to achieve its aim and objectives as stated. Few modifications have been suggested by some of the users which will be taken care of in its future course of work.

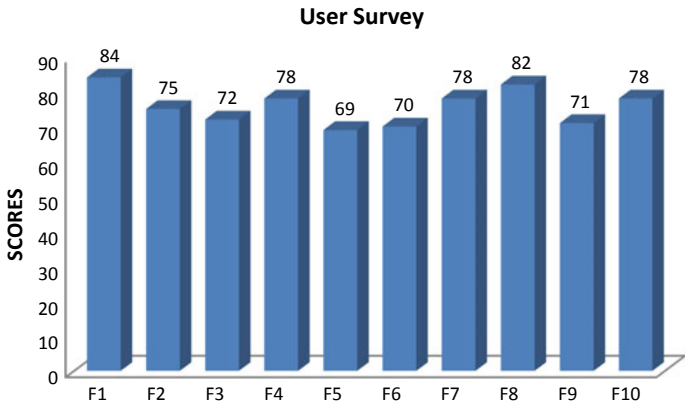

Fig. 10 Graphical representation of the user survey

7 Conclusion

The system of personalized or private tuition is equally exercised in the localized area alongside normal academic classes at school. This mobile application will help the parents or students to find a desired tutor in their locality for all specified subjects. The classes can be taken in offline mode as well as online mode using third party application, according to the convenience of both teacher and students. The students will have a list of all available teachers nearby, and thus will have a choice a selecting a perfect tutor according to their need. This application will also provide the young and recently passed out graduates an opportunity of employment through tuition. The future scope of this project opens up an exploration into new domain of personalized and home tutoring with advanced use of technology and devices.

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An Intensive Analysis of the Problems and Strategies Implemented During the COVID-19 Outbreak: Mitigate, Recover, Rehabilitation and Build Resilient Communities

Riya Shroff, Ganesh S. Jadhav, and Pankaj N. Dhatrak

Abstract This paper highlights the problems faced during the pandemic, as this pandemic caused adverse ramifications and washed out many vulnerable communities. Healthcare systems and providers raised their capabilities and capacities promptly to battle challenges that were unprecedented. Yet, a lack of prompt response has led to huge global losses in all the major sectors. Hence, after analysing such vulnerabilities, how can communities resist and withstand such vulnerabilities to survive. This paper recommends the elements of resilient communities and aims to contribute six futuristic strategies from the identified pitfalls and the potential scope for mitigating the impact and accelerating the road for recovery and resilience. Acknowledging the social change, this paper also presents a product solution to protect oneself from disorders caused by the SARS Covid-19 virus. This ergonomically designed product is versatile, and its unique features make it user-friendly which will protect, revive, and recover the immunity for users of all age groups and especially the ones who are always on the go. This will imbibe a positive behavioural change for the well-being of the users paving the way for quality life.

Keywords Covid 19 · Community resilience · Pandemic · Product solution · Quality life

1 Introduction

Covid-19 is a disease caused by the virus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which is spread between people in close contact through the aerosols and droplets, either in the air or also via common and contaminated

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surfaces. A mass gathering can amplify the transmission of the virus. This virus has affected 173,380,598 individuals in the world and 37.1 lakh deaths [1]. Not only this but has impacted every living system directly or indirectly and demolished many subsequently [2]. Widespread and long lasting ramifications arise surpassing the geographic scales and boundaries adversely affecting governments, businesses, transportation, economic sectors, and so all people [3]. As theories quote, most fundamental human need is to function effectively in one's community. But is it possible post pandemic [4]? Though few & common key adherences mitigated the entire situation: (i) Enforced wearing of face coverings (ii) Restricted crowd in public places (iii) Accessibility to hand-hygiene [3].

A community is a social unit sharing a commonality on the basis of geography, religion, practices, occupation keeping them close and cohesive. A community is close-knit due to the factors like (1) membership, feeling of belonging or of sharing a sense of personal relatedness (2) influence, mattering, making a difference to a group and of the group mattering to its members (3) integration and fulfilment of needs (4) shared emotional connection. As the great Greek philosopher Aristotle also quotes "Humans are social animals". This is inherently embedded and its most important element is Communication which leads to the formation of a Community [4]. But the cohesiveness and communication among a community were intervened by a virus which is not even visible to the bare eye. This has accounted for unforeseen consequences leading to hardships, misery and misfortune. Such adversities and crisis situations often lead to the degeneration of a community and makes it vulnerable. The resilience and vulnerability of a community to a crisis situation are multidimensional inclusive of economic, social, infrastructure and environmental. The array of qualitative and quantitative data analysed during the research includes considerable development of models, frameworks and indicators in the last few decades to build such robust communities. But the research results show that these model frameworks do not impact until Preparedness exists [5]. Preparedness and possession of a community with the elements listed below is the step towards building tenacious societies. When I compared the current scenario to the ideal scenario of strong communities, I realised the trigger points in the whole system. It is imperative for them to be addressed in order to be surpassed. But, most communities lack either one or more of the prerequisites for building a resilient community and hence that is what makes a community more vulnerable and far from being resilient. Based on the research findings, we discuss the requisites, challenges, changes, best practices, action plans and implications by each actor in the course of the pandemic. This helped evolve and understand the elements to build stronger communities for the future.

An augmented capacity to anticipate threats which reduces the overall vulnerability and enable the recovery post a crisis is known as the resilience of a community [6] This research paper focuses on deciphering a system's capacity to accept and absorb disturbances, to change, learn and reconstruct into a completely functioning system following a crisis the system is suffering from or suffered. In other words, the potential of a system to mitigate and recover from a crisis and build back better. Addressing the socio-economic consequences and management of such crises requires audacious policy action for vigorous functioning of healthcare systems,

access to education, assured jobs, preserving businesses, and stability of financial markets. This is necessary to coordinate and collaborate agile responses at all arrays of the system. The capacity building by strategic planning of centres of government plays a key role to manage government operations efficiently in the midst of the pandemic. Governments are building rapid, efficient and coherent emergency responses to managing the immediate dire cascading economic and social consequences [5]. Based on standard protocols and procedures, the traditional emergency management have thus proved to be insufficient. Hence, to avoid the exposure to such distress circumstances, it is necessary for a community to possess elements such as accurate information, local knowledge, networks and relationships, adaptability, governance, and leadership, and finally community capital in order to mitigate, recover and be resilient for the future.

The impact-centred design of the product solution resulted from the human-product interactions mapping the conscious and subconscious effects, along the strategic pathways that were executed to achieve these effects optimally. Acclimatizing in the "new normal", the product is designed in a way to evoke a sense of security, trust and assurance along with being convenient and adaptable. This will benefit the user not only physically but also psychologically, which means elevate productivity and efficiency and decrease discomfort. As it is involving easy body movements while the use of product, the movements user is already aware about, makes it an accessible and feasible solution.

2 Community Resilience and Its Elements

Uncertainty is the most common feeling amongst the affected population during and followed by a disaster. A reinforced local capacity with an extension of social support and resources, results in decreasing trauma, risks and miscommunication [6]. Empowerment and collective efficacy compose a positive system and amplify the community's ability to overcome potential effects and hardships caused by a disaster. Relief can be synthesized, assembled and be transferred with attributes like- (1) Personal and community preparedness (2) Civic responsibility (3) Effective bystander responses and (4) Self-and community-reliance [6].

The importance of preparedness on an individual, family or government levels have been mentioned as crucial [5]. Along with that, risk assessment is also vital and plays a major role to identify vulnerabilities. Critical importance was protecting vulnerable populations, which were identified with the practise of risk assessments. Significant rise in mortality rate of folks 60 years of age and above highlighted the vulnerability of this group of the population regardless of any comorbid conditions [7]. The pre-existing health of a community and the accessibility to health services in and after a disaster are called vital for community resilience. Hence, understanding and addressing all sets of vulnerabilities to prepare a community, mitigate vulnerabilities and major impacts, and forge a road to better and stronger communities [7]. The immediate trauma of facing a disaster can lead to a range of disorders like anxiety,

depression, and post-traumatic stress in many individuals which claims the degraded mental health of a community. Therefore, along with first aid, psychological aid after a disaster may help mitigating and coping up with lesser dilemmas [7]. This also enforces the importance of having mental stability, hence bolstering psychological wellness to be able to restore and recover efficiently. Therefore, mental outlook plays the most determinant role for building resilience in a community, with a balanced focus on sub-elements of adaptability and hope. The most important elements of a community to prevent or mitigate the impact and recover from a disaster are explained in the following subsection.

2.1 Access to Accurate Information

For directing coordination to provide aid of any form, effective communication is obligatory to understanding upcoming risks and to diminish the existing obstacles [3]. Access to up-to-date information for community members about the ongoing impact should be achievable to acquire relief efforts. In most cases studied, patients and other seekers suffered majorly as they could not access the required appropriate information in order to receive treatment or any sort of aid. This leads to extensive losses and enforces the importance that even after the presence of help, it does not reach to the seeker due to inaccessibility in ways to communicate or ignorance by leaders responsible.

2.2 Local Knowledge

Knowledge of one's own community helps perceive how to sustain a disaster. Awareness of vulnerabilities, recognized through assessments, can mitigate the short-term or long-term effects of a disaster, because if these vulnerabilities are addressed prior to a disaster, there shall be less damage and losses [6]. In times of scarcity, a community representative with local knowledge can easily reorganize any form of relief. The factual knowledge associated with disaster preparedness, mitigation, response, and recovery proves to be imperative. Training and education, leading to adherence and awareness have been proposed as useful.

2.3 Community Networks and Relationships

Connectedness and cohesion within the community have been seen to help people deal with uncertainty and create a positive system eventually. It strengthens the

community based on the shared values and interests. Research proves that a community with strong relationships among one another proves to be more secure and resilient than other communities [6].

2.4 Adaptive Capacity

The competency to accustomed to the new life, equate the aftereffects of a disturbance, and survive defines the capability of a community to build resilience. Community health and well-being evolve social capacities. Hope can be a vision, quoting it to be one of the inherent aspects of resilience that depicts a better future post disaster [6].

2.5 Governance and Leadership

Governance and leadership are quoted to be essential aspects that shape how communities respond and recover from crises. Infrastructure and services, community's economic assets, their involvement and support are what build the pillars of strong and secure communities [6]. Response capacity including the number of fires, police and all other emergency provisional relief services including government policies define the evacuation capabilities and redundancies. Also called as the infrastructure and economic resilience of the community. Hence, there is an urgency of social systems supporting disaster preparedness, hazard mitigation, planning, and rapid urban development to protect the communities.

2.6 Community Capital

To attain commercial and operational resilience, community capital is the only mode to support the process of action ability. It enables the survival and sustainability of communities by (i) Distributing resources. (ii) Economic planning and programming. (iii) The rapid development of infrastructure to bounce back better and stronger.

Proactive investments can help in rebuilding the economy of an affected community. Compensation policies and reimbursement schemes adaptation by the Government is needed to provide to the affected for recovery. Higher-revenue generating procedures, with the help of forecasting and stress testing to recognize achievable model options and scenarios to mitigate losses [6, 8].

Because there are no definitive characteristics of a resilient community, the selected characteristics were subjective. They are based on the internal capacity and consistency of a community. Community involvement and the support that

comes along in groups like social advocacy organizations and religious organizations conceives recovery. Religious organizations fruit in linkages among families, friends, acquaintances and people, whereas social advocacy organizations drive pre and post-crisis support through outreach services, community redevelopment, and the capacity to reinforce resilience [6].

3 Challenges Faced During the Pandemic

A considerate interpretation of the on-ground problems in the pre and post phases of the pandemic. This leads us towards what the community lacked majorly so that we are able to build better societies for tomorrow, with less sufferings, losses and be able to cope up efficiently.

- All forms of control and prevention of infection for example by sterilizing equipment for further use, environmental cleaning/disinfecting surfaces, especially public surfaces to avoid transmission of virus. (Indian Political Association Committee).
- Prompt communication of challenges, requirements, and provision of assistance. Also providing and receiving accurate information, avoiding delays by consulting/notifying health professionals consistently for immediate action.
- Diagnostic and rapid testing, evaluation of results to start with immediate treatment.
- Education and awareness about the precautions, adherences from the Government.
- Personal protective equipment (PPE kits) along with accessible hand sanitizing stations for patients and healthcare providers.
- Government policies and schemes for the underprivileged, visitors, families who lost their breadwinners and also the frontline workers.
- Providing resources, medical supplies, and equipment.
- Social distancing in public spaces, surveillance & monitoring places of mass gatherings, space for hospitals and isolation, early mobilization, restrictions on movement and transportation of regular citizens [7].

4 Strategies for Resilience

Strategies are action plans directed on the scope of the goal with the optimum allocation of resources required. They usually have better chances of acquiring the attached purpose, hence are optimal. In a complex system of a community “Fig. 2 shows the various parts of the whole ecosystem”, it is required at all levels to surpass not only the marked potential but for the security and sustainability of the community. Existing Healthcare systems need to commit to rapid adaptation and enforcement of better, more efficient solutions to overcome challenges, as they now serve the ‘new resilient reality’.

The five key areas to consider are:

4.1 Testing and Surveillance

A need to implement and scale mass testing accessibilities to enable rapid treatment and isolation for those with active infections or exposed to the virus closely. This will rapidly distort the pace of the spread. Also healthy individuals are obliged to follow rules and restrictions to avoid stressful consequences.

4.2 Population Based Approaches

Vulnerability assessments for specific communities can raise awareness and preparedness factors. Gearing up with required precautionary measures and incorporating elements of stability can bring a huge change. Resulting into mitigating risks and escaping the vulnerability, instead constructing resilience.

4.3 Digital Delivery

Accelerating the digital technology enforcement by anticipation and planning across the entire service with the help of data and analytics modelling. Command centres can administer and arrange for services like consultations, treatment and constant monitoring of the health of the patient from the on-ground situation. Supplies can be fulfilled with the help of statistical data acquired from the digitised system, fed by the healthcare providers and optimum distribution of resources allowing efficient results.

4.4 Agile Workforce

Enhanced collaboration, effective coordination and rapid optimization of human tasks can be more flexible and remote. Cross-working and redeployment between departments, participation from public volunteers and third party availability provide support and reduce the burden on existing staff.

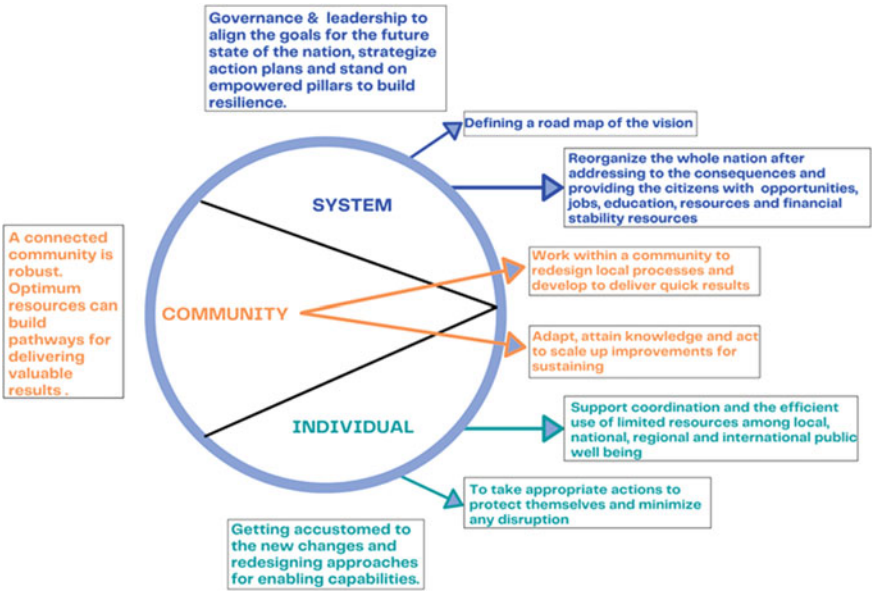

Fig. 1 Role of the system, community and individual in order to reinforce strategies to accomplish resilience at all levels

4.5 Developing New Care Models

Informed decision making, resource planning and supply management through digital command centre, which processes real time data. These innovative care models are diluting the painful impact and effects. Non-medical facilities such as hotels, and other 'pop-up' facilities are pacing the treatment. Online triage set up by many organizations and governments observed to ease out the process and lessen the chaos.

4.6 Operational Resilience

Digital command centres can elevate the operational efficiency systems in order to manage and combat the system-wide inefficiencies. Defining trigger points and overcoming vulnerabilities is eliminating the obstacles in the way to bounce back better [8]. "Fig. 1 shows the roles at all levels."

5 Product Solution

A unique product with a versatile solution that positively impacts the user's life with its multipurpose benefits. It will be a requirement to all once the world resumes back to normal, to keep themselves protected and revive immunity. Its appealing aesthetic, ease of accessibility, lightweight and portability, and multipurpose functionality proves to be life changing benefit for all users.

5.1 Need of the Market

What will happen when the world resumes back to normal?

What is the mind-set and change in behaviour of people post pandemic to travel around?

The answer to all these questions started with understanding behaviour patterns, feedback loops inherited, psychological effects, and needs. Furthermore, the most important was to gain trust as they make apparent the potential of design to make a valuable contribution. Only then could they believe in my belief and the product's ultimate purpose [6]. Adaptability, Acclimatization to Regain and Recover is the only formula to survive.

A microscopic virus which has revolutionised and impacted all lives in tremendously unanticipated ways. Causing endless sufferings, pains, losses of assets, happiness and closed ones. But as Darwin quotes "The Fittest will Survive" [9]. The world is resuming with major transformations and regulations with more sanitizer stands at a mall than the people, and all attires with a new accession—the mask. We all are implementing colloquialism to maintain healthy immunity by practicing multiple precautionary measures.

As I commenced my research it involved developing strategies that could fulfil the core need which can inculcate a feeling of security among users and on "how people can actually protect themselves while in public places or transit'. The behaviour patterns and strategies people are instilling in their routine to keep themselves healthy and recover made a headway and—a compact, portable electric device, battery operated producing nano-ionic steam with a click in just 4 min, ready to inhale and also can be used to carry about 300 ml of hot beverages to anywhere an individual may travel. The sleek and stylish form, ergonomically efficient, automatic, handheld and lightweight makes it captivating. Its optimality and its exponential target audience shall appeal to a multitudinal audience and be a trendsetter of the market.

5.2 Product Design and Specifications

A multi-dimensional product that saves your hassle of hovering over a steaming bowl. Boosting immunity, providing relief from congestions, and maintaining a healthy well-being. This product allows one to carry it when in transit, allow inhaling steam and consume hot water/beverage. The unique design is user-centric to allow optimum advantage. The peak of the mouth focuses the steam output on the nose and the mouth. The lid of the product is leak-proof. The slider button under the lid allows control of the steam output to attain dense/soft steam as per the user requirement. The plastic body allows to carry 300 ml of water and is also insulated from the inside with silver to avoid heating of the product. The rubber grip allows accessibility and lower rubber support avoids spillage, absorbs shock. The safety index hence proposes an exponential audience. The lower compartment includes a heating element attached to a battery with the capacity of 37 Wh and a charging port where a cord of 1.5 m can be used for charging. Once fully charged, it can provide almost 2–6 doses of steam for a total of 30–40 min. The heating time would be 3–4 min for the steam to be produced. The dimensions are 16 × 12 cm in height, 6 cm of radius and the weight from 500 to 700 gm. The manufacturing process would be injection moulding and the rough cost would be in the range of 600–900 Indian rupees.

5.3 Product Interaction Due to User-Centric Ergonomic Consideration

The intriguing aesthetics revives a sense of trust and curiosity to experience. This product's ergonomic considerations make it handheld and user centric. The interaction is effortless and accessible. While in use, the user is sure to feel a sense of security with an overall phenomenal experience. The body parts included during the use are palm to hold, fingers to grip, wrist to make the movement, nose to inhale steam, lips and mouth to intake of the beverage. The user can simply sit at any space and position to use it as a steamer and while being using it as a sipper, the basic drinking action after sliding the button to shift the lid and switch the function. The rubber grips and the slider to control the steam output make it safe for children to use as well, as the output can be monitored [10] "Re (Fig. 2c, d)". This also validates, if the product being used while kept on a platform, it will avoid spillage due to the rubber bottom. While inhaling steam, the peak of the lid exerts the steam in the direction of the user, due to which the entire output is incremented "Re (Fig. 2b)". Hence, can be considered as a competitive advantage and ergonomically considerate. Or while using it with the sipper, the slider button is an easy sliding mechanism to switch the use of the product, familiar to all users and is leak-proof "Re (Fig. 2c, g)". Slide, to switch the function, it is that easy! When use is completed, setting it up for charging is a familiar task that can be performed by each one [11] "Re (Fig. 2f)". The rubber bottom makes it stand on any surface objecting spillage "Re (Fig. 2f)". The

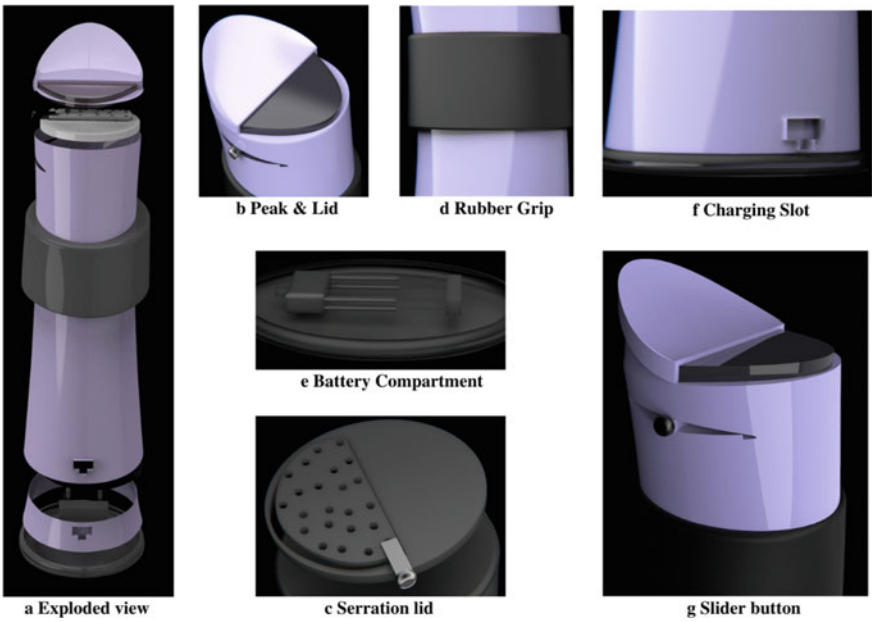

Fig. 2 An ergonomically user-centric, unique steam jar product

plastic body, ergonomically considered height and weight makes it light in weight, hence validating the portability of the product. All this together, leaves a positive psychological impact and an impression of relief. Due to which, people would make it a part of their enhanced routine in the new normal [12]. They would also feel content with the fact of how conveniently and efficiently they are able to take care of themselves without much time or effort consumption.

6 Discussion

The research results prove that the practices utilized in the current scenario were not optimal. They resulted into some short comes, leading to loss, sufferings, and elevation of the challenges. They needed to be mitigated in time but was not achieved. Hence, it is validated to establish certain futuristic strategies with the vision to make India a developed nation and be strong-armed to cope up from any such catastrophe, there is a requirement of building robust systemic approaches to handle such a crisis. This will formulize the resources by block chain supply methods, training of frontline warriors with digital care systems, and governmental policies will provide security to citizens and awareness along with adaptability of all individuals will build a coordinated response and rapid recovery to such a situation.

7 Conclusion

The "new normal" demands individuals, community and system to adapt and develop new strategies to survive and sustain. As we know we all play magnificent roles in modest ways. The interpreted hypotheses can be evaluated upon from the identified pain points and the potential pockets to execute strategies which can help cope up efficiently from the catastrophe for a better and secure tomorrow. This paper discusses the strategic and institutional planning from a higher to lower level to manage the response which can assemble the way to Resilience. As the governments, citizens and in fact, every living being have faced unprecedented challenges, the pandemic has uncovered gaps in both which directly affect the nature and quality of the measures adopted to tackle the crisis and its aftermath. These challenges have led to a number of quick fixes and agile responses, which can be assessed and quoted to be not the solitarily optimum. Hence, to conclude, the above mentioned 6 strategies for establishing resilient communities and 6 elements that prove communities to be resilient are keys for tomorrow's survival. Not only the strategies but also an inculcated behavioural change with the use of the product shall prove to be lifesaving.

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Rotating Cylindrical PIN VR Display—An Ergonomic Approach for VR Scripts

Delwyn Jude Remedios, Deepak John Mathew, and Max Schleser

Abstract A Rotating Cylindrical Display is recommended as an ergonomic approach for the communication of scripts in Parallel Interactive Narratives in Virtual Reality (PIN VR). VR studies propose grammars to orient a navigator's gaze towards intended areas; however, it is argued that it is this limitation of the navigator's ability to choose their own viewing direction, which restricts the full potential of the medium. PIN VR experiences address this limitation by allowing the navigator to teleport from one narrative location to another; while the remaining narrative locations run in parallel sequences, irrespective of the navigator's presence. A study on scriptwriting for VR reveals that there is no standard approach for VR script design. This leads to the possibility to explore scriptwriting for PIN VR experiences. Through a Screen Production Enquiry, a PIN VR script has been attempted in a Traditional and Spherical Format. It is observed that these formats limit the representation of parallel narrative timelines. An ergonomic solution is found in a combination of a Tabular Format and a Rotating Cylindrical PIN VR Display. The display includes parallel scripts mounted around the surface of a cylinder. The display adopts relevant ergonomic and functional details from a rotating literature rack and a digital kiosk display. The Rotating Cylindrical PIN VR Display has been tested with VR production crew members for its ergonomic and visual communication effectiveness.

Keywords Rotating cylindrical PIN VR display · Scriptwriting · Virtual reality · Parallel narratives · Visual communication ergonomics · Screen production enquiry

1 Introduction

Parallel narratives in cinema have a unique way of depicting the chaos and randomness of human life [1]. While parallel narratives have been present in early cinema

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[2], they are rapidly prevailing in mainstream cinema; and their complex structures present a craft challenge [3]. Virtual Reality (VR) is one of the latest disruptions in cinema that has confronted the cinematic landscape [4]. Cinematic VR invites viewers to step into the cinema frame borders and look anywhere they desire. This radical transformation contests a VR filmmaker to discover new approaches to cinematic narration [5]. Research on Cinema 3.0 indicates that the increase of interaction in cinema has transformed the role of a passive film 'viewer' into a 'navigator' [6]. As a VR experience is immersive, and often interactive; this study repositions the VR 'viewer/user' as a 'navigator'. Though several studies on VR grammar suggest methods to direct the navigators eye towards intended areas of a VR canvas [4, 7]; it is argued that a VR experience should provide the navigator with the freedom to choose their viewing direction [5]. The navigator's freedom in a VR environment can be addressed by exploring Parallel Interactive Narratives in VR (PIN VR).

1.1 Parallel Interactive Narratives in Virtual Reality (PIN VR)

Studies reveal that there are limited experiments conducted in the area of parallel narratives in interactive experiences [8–11]. This paper proposes PIN VR experience as an alternate form of parallel narratives in VR. Reviews on CVR [4], Seamless Multi-thread VR experiences [12] and Cinévoqué [13] have assisted in positioning a PIN VR experience on a scale of interactivity as shown in Fig. 1.

A PIN VR experience allows a navigator to teleport from one narrative location to another; while the remaining narrative locations run in parallel sequences, irrespective of the navigator's presence. The unique feature of PIN VR is that the navigator's progression results in a time lapse in each parallel scene. Teleportation takes place through gaze and gestures fixated at Pin point areas in the VR environment. Therefore, an abbreviation of Parallel Interactive Narratives in Virtual Reality is derived as PIN VR. The concept of PIN VR is explained further with an example. A VR narrative experience that begins at a classroom in an academic building, would offer a certain narrative to the navigator. If the navigator decides to exit the classroom and step into the courtyard, there is another narrative taking place in that scenario, while the classroom narrative continues in parallel. This process can continue, leading to an

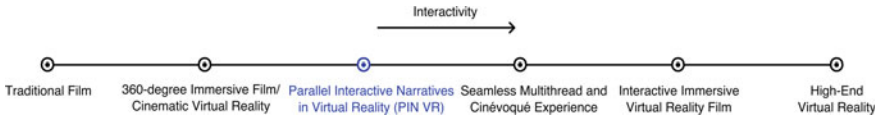

Fig. 1 Positioning of PIN VR experience on a scale of Interactivity

infinite narrative possibility. An advantage of a PIN VR experience is that it encourages the navigator to engage in multiple viewings of the experience to get a deeper perspective on the interconnected plots.

VR researchers have primarily focused on the technological capabilities of VR, while there is lack of study on its theoretical aspects [14]. This paper emphasizes the script development process, which is an initial stage in cinema pre-production. It is essential for a director to communicate the script to the crew members for clarity of vision. This study examines the use of an ergonomic approach for visual communication of PIN VR scripts.

2 Literature Review

2.1 Visual Ergonomics

A definition of Visual Ergonomics on the International Ergonomics Association (IEA) webpage (2012) states that, "*Visual ergonomics is the multidisciplinary science concerned with understanding human visual processes and the interactions between humans and other elements of a system. Visual ergonomics applies theories, knowledge and methods to the design and assessment of systems, optimizing human well-being and overall system performance. Relevant topics include, among others: the visual environment, such as lighting; visually demanding work and other tasks; visual function and performance; visual comfort and safety; optical corrections and other assistive tools* [15]." As the definition recognizes the multidisciplinary nature, this study examines the use of visual ergonomics to benefit communication of scripts in VR narratives. One of the domains in visual ergonomics includes visual display and information design [16]. It has been stated that the vital success of a business stems in receiving communication in the way that it was intended [17]. Jackson, S. adds that the message has to be designed in a manner, so that it is communicated to the receiver. In this study, the message is a PIN VR script, the communicator is the VR director and the receivers include VR production members. With the intention of developing an effective design to communicate a PIN VR script, scriptwriting for traditional cinema has been revised.

2.2 Script as a Blueprint for the Traditional Cinema Crew

Scriptwriting for cinema is commonly known as screenplay writing. Industry professionals have described the meaning of screenplay for cinema [18]. According to Linda Seger, a screenplay includes "*Five things: the story lines, the characters, the underlying idea, the images and the dialog.*" Alan Armer adds that a screenplay is

"*A blueprint for a movie.*" William Goldman comments that "*Screenplays are structure.*" Linda Aronsen states that "*A screenplay is a technical instruction manual for everyone involved in the process of creating the film* [19]." The screenplay works as a guide for the Producers, Director, Casts and Crew. It aims to communicate what will appear on screen [20], so that all production members have a similar understanding of the narrative. Once the script is prepared, it is shared with production crew members in a prescribed format [21]. A conventional narrative structure primarily follows a three-act structure in a linear chronological order of events, experienced by a single protagonist on a journey towards a goal. The following review inspects script structures for parallel narratives.

2.3 Parallel Narratives in Cinema

A narrative structure which includes interconnected plots is addressed by a variety of names such as "network narrative" [3], "hyperlink cinema" [22], "smart film" [23] and "parallel narratives" [24]. Linda Aronson describes parallel narratives "as several separate narratives running in parallel, often involving non-linearity, time jumps, large casts, or all of these [25]" Porter Abbo claims that parallel narratives in mainstream cinema is "yet one more way in which narrative worlds replicate the actual world we live in" [26]. As the term 'Virtual Reality' is inclusive of the word "reality', this study argues that parallel narratives in VR can significantly contribute to bridging the gap between cinema, interactive experiences and reality. Aronson mentions that there is lack of film theory available for writers who want to use parallel narratives structures. However, most of the parallel narrative scripts refer to the three act model, by splitting up, re-arranging, multiplying or truncating the script [25]. Explorations are necessary to disclose if these methods would work for VR experiences.

2.4 Conceptualization and Scriptwriting for VR Experiences

A review on Scriptwriting for VR reports approaches to script formats by three Australian VR practitioners, Mike Jones, Tom Phillips and Lynette Wallworth. A summary of the interviews recommends the benefits of a Writers' Room, which includes key professionals from different areas of screen production to collaborate during the conceptualization period. A Test Shoot is advised during the early stage of the project process in order to understand the perspective of the navigator. A linear script could have limitations if the VR project is designed to include choices for the navigator. It is mentioned that the location plays an important role in shaping a narrative. This review concludes that there is no standard approach to design a script for VR. Traditional cinema forms like documentary, fiction and corporate films have

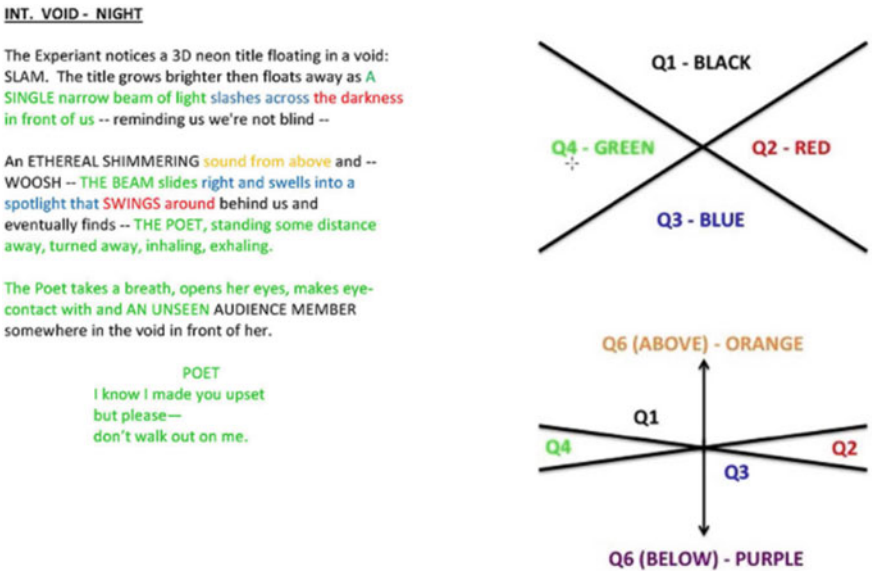

Fig. 2 A sample page from the screenplay *Slam* by Aja Cooper and Gary Tieche [28]

their own unique methods of scripting. Similarly, scripting for the various forms of VR could have a variety of approaches [27].

Aja Cooper and Gary Tieche establish a script format for their VR experience *Slam* [28]. Their method demonstrates how a VR script includes actions represented in 6 planes (front, back, right, left, up and down.) as shown in Fig. 2. Colours have been effectively used to correspond the sound text and plane.

Another example depicts the different points of view integrated into a linear traditional format [28]. From these examples, it is clear that scriptwriting for VR is currently under explorations by VR theoreticians and practitioners. Multiple studies recommend that VR production could draw references from theatre techniques.

2.5 Comparisons in Theatre, VR and Street Theatre

Louchart et al. consider VR as a narrative medium alongside Theatre, Literature and Cinema [14]. Bolter et al. (2003) mention that their Augmented Reality Experience *Three Angry Men* borrowed the acting style of theatre [29]. Gabler et al. additionally acclaim that theatre techniques can aid staging in VR [5]. Sheikh et al. propose scope to explore the approach of storytelling in theatre, as the theatre has a similarities to this medium [30]. Wooksang compares theatre and VR in Table 1 [31]. This study adds Street theatre experiences to Table 1; as it is observed that Street theatre has additional similarities to VR.

Table 1 Comparison between Theatre, VR and street theatre [31]

	Theatre	VR	Street theatre
Acting	More exaggerated	Detailed and exaggerated	Detailed and exaggerated
Visual mood	Artificial	Both realistic and artificial	Both realistic and artificial
Focus of acting	More gesture than face	Both face and gesture	Both face and gesture
Viewer	Audience	Camera and audience	Audience
Space size	Limited	Unlimited	Unlimited
Camera/audience	One position	Both (one position or multiple positions)	Both (one position or multiple positions)

The following questions have been derived from the Literature Review: -

- Are the scriptwriting recommendations of writer's room, location, test shoots, colour codes, and street theatre techniques valid for PIN VR conceptualization?
- Can visual communication ergonomics be effectively used to communicate a PIN VR script to the VR production crew members?

These queries will be addressed by exploring various conceptualization and scriptwriting approaches for a PIN VR experience.

3 Methodology

Kerrigan and Callaghan (2016) identify "screen production enquiry" as a part of a broader practice research paradigm known as practice-led, practice-based and creative practice research, where films are created as research outputs. *Research in screen production is by no means a homogenous activity but usually involves the production of a film (or other screen work), an iterative process of practice and reflection by a researcher who is also the screen practitioner, and a theoretical perspective that informs the overall research* [32]. This study adopts the iterative process of screen production enquiry to develop a scriptwriting plan for a PIN VR experience.

In order to perform this enquiry, a VR artefact titled *Table for Two* has been conceptualised. *Table for Two* is a PIN VR experience, which pivots around interconnected conversations across 4 tables in an urban café. This experience is designed to encourage the navigator to teleport between tables; and engage in multiple viewings of the same experience for an 'in depth' understanding of the plot.

4 PIN VR Conceptualization Process

The Conceptualization Process for *Table for Two* included the Writers' Room, Test Shoot, Staging and an exploration of Scriptwriting formats. There were two members involved in the Writers' Room. Both members' experience contributed towards shaping the concept. The concept originated with the location of a café as an ideal location for diverse conversations across tables. A Test Shoot was conducted to understand how the navigator would view the experience. While the initial concept had 360-degree cameras plotted at the center of the tables as shown in Fig. 3a; the navigator would require to rotate at a 180-degree axis regularly to toggle between two performers in conversation. It was observed that the 360-degree cameras at the center made the performers appear inappropriately close to the navigator. These ergonomic issues were resolved, by revising the camera location. Taking into consideration the navigators comfort and ease of use, the 360-degree cameras were re-positioned as a third member at each table as depicted in Fig. 3b. The revised placement of the 360-degree cameras and performers in the café are represented in a top angle view in Fig. 4. This diagram was shown to crew members prior to the script.

Scriptwriting for PIN VR. The scriptwriting process for *Table for Two* includes multiple iterations. Figure 5 displays each narrative with colour codes in order to distinguish one from the other. The VR director presented each iteration to six VR production crew members; a cinematographer, casting director, an actress, sound designer, an ambisonic sound expert and a technical expert. The casting director and actress were selected based on their experience in street theatre. Each participant's argument for and against the formats have been reported and discussed.

Traditional Format. The scriptwriting process was initially approached in a Traditional Format. Each parallel script was written in separate documents as represented in Fig. 5a. The collective crew member's feedback revealed that ergonomic limitations was in the linear representation. The navigator could read one script at a

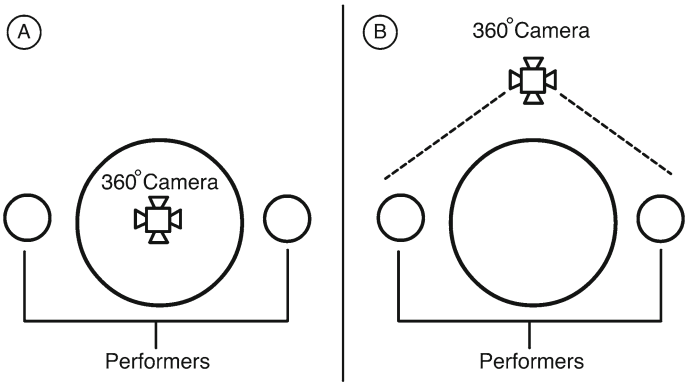

Fig. 3 360-degree camera placement for *Table for Two* PIN VR experience

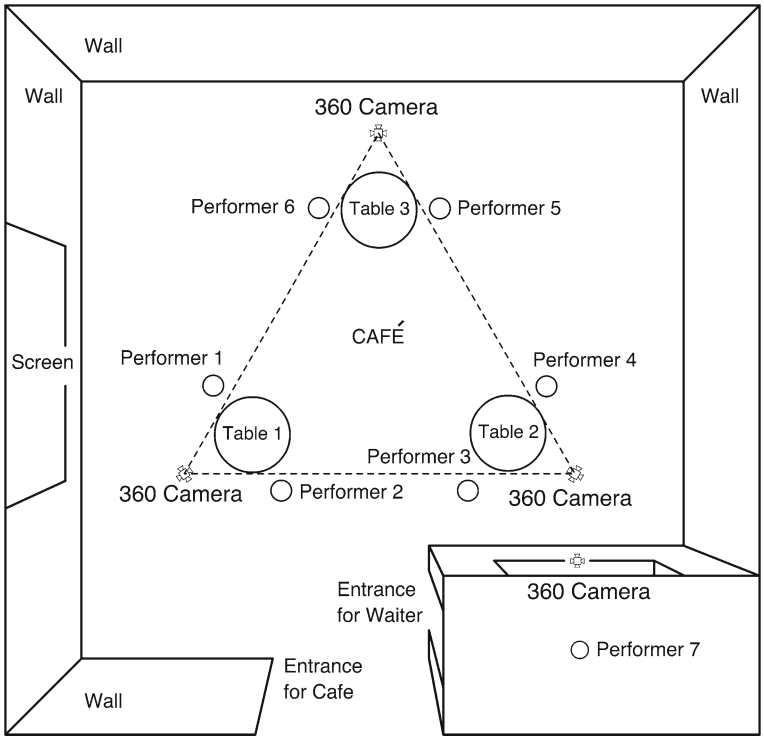

Fig. 4 Staging in *Table for Two* PIN VR experience

time, without correlating the events of other parallel narratives. This limitation was addressed by plotting 4 scripts in a tabular format.

Tabular Format. The Tabular Format presented an individual script in a separate column, while the rows indicated parallel narratives as shown in Fig. 5b. The starting point of the PIN VR experience is presented at the top of the table, while the end of experience is shown towards the bottom. However, each parallel narrative can have its own starting and ending point. The participants mentioned that the Tabular Format allows the navigator to focus on one narrative if required, while linking the events to other parallel narratives. The casting director mentioned that it was initially confusing as one is used to reading a script from left to right, however once he got used to it, it was convenient to navigate. Questions were raised if this could be available on the set during rehearsals and production. A concern was raised if longer format scripts would work with this format. For example, if there were ten parallel narratives, the distance between the first and tenth script would widen. While the ergonomics of Tabular Format solved the main communication issues, it was evident that the distance between the first and last narrative would extend with the increase of parallel narratives.

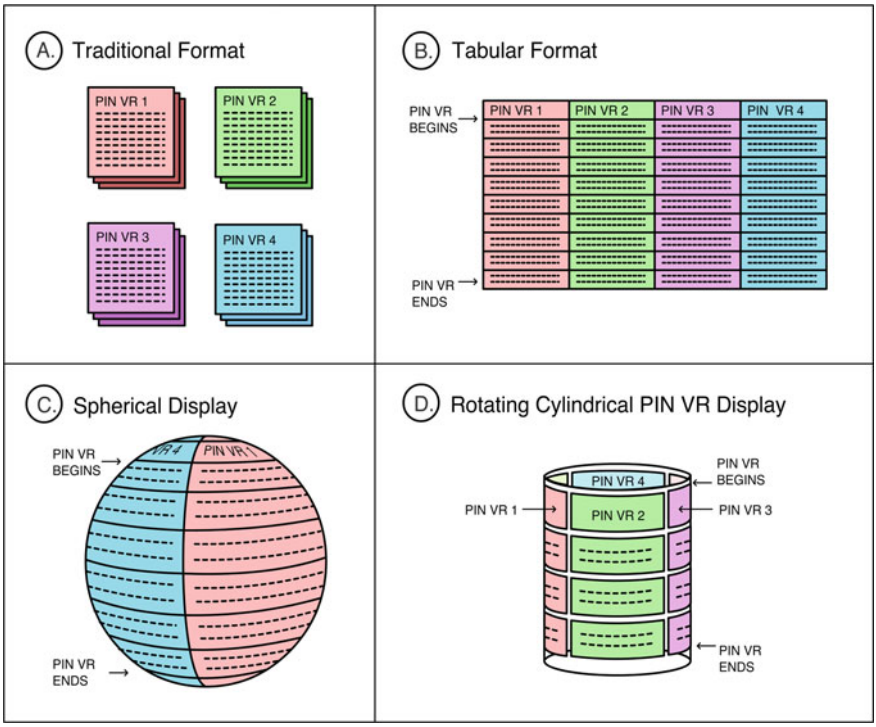

Fig. 5 An exploration of Scriptwriting formats for a PIN VR experience

Spherical Display. The inputs from the crew members were taken into consideration and the Tabular Format was altered into to a Spherical Display as shown in Fig. 5c. However, the converging lines in the sphere distorted the script information at the poles. The members expressed that the ergonomics of this display were not navigator centered, due to which an alternative form was considered.

Rotating Cylindrical PIN VR Display. The team experimented with an accessible water container. The Tabular Format script was dissected into segments and mapped onto the surface of the water container. The cylindrical form of the container provided the flexibility for the navigator to rotate the bottle in any direction as per their convenience. A representation is shown in Fig. 5d. The next step involved transforming the concept into a tangible display. Required functional and ergonomic details were adopted from a Rotating Literature Display Rack [33] and an interactive kiosk [34] as shown in Fig. 6. The average Indian height was taken into consideration [35] and a readability test suggested that the font Helvetica at size 16–20 was appropriate to read the script on the display. The display was tested with the VR production crew members.

The casting director pointed out that such a device is very useful for theatrical 'Reading' sessions. He discussed that actors and actresses often flip through multiple

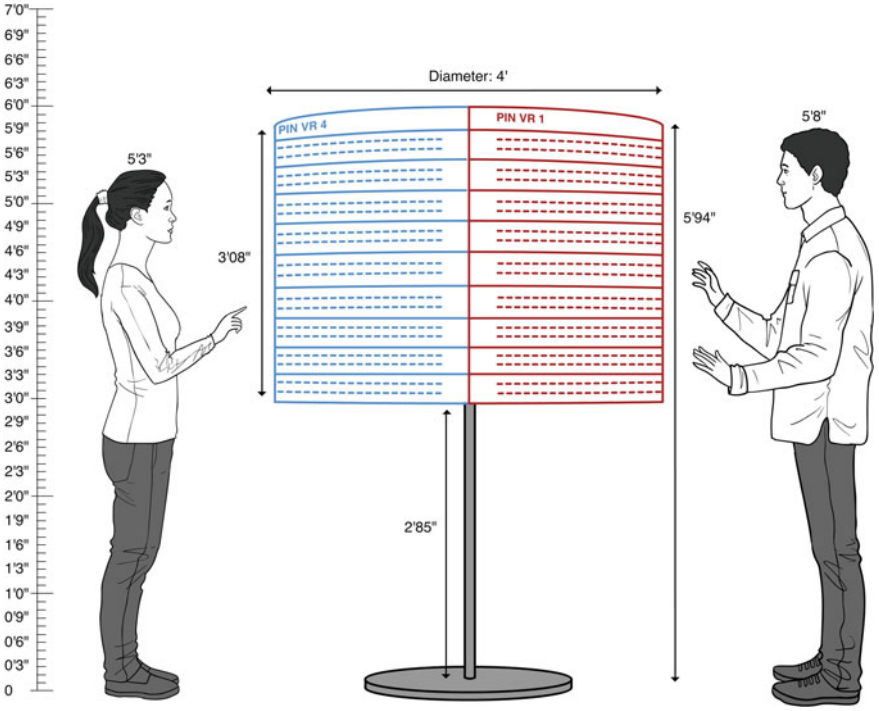

Fig. 6 Rotating cylindrical PIN VR display

sheets to locate their dialogue during rehearsals. The availability of such a display during set rehearsals would aid the run through. The actress mentioned that this display helped her understand the concept in an effective manner. She recommended that this display should be available on set, while a printed version of the Tabular Format can be taken home for independent rehearsals. The sound experts mutually mentioned that they were used to traditional approaches and new methods might take time to be exclusively adopted. The technical expert found this approach suitable for the script *Table for Two*, however had queries on how this display would represent longer scripts. It was observed that the cinematographer alternated between rotating and walking around the display to read the scripts. He declared that display helped him to understand his role and the parallel script details in a clear manner.

5 Discussion

The Rotating Cylindrical PIN VR Display noticeably helped the participants understand the parallel narratives individually as well as in harmony with other narratives. It was observed that the crew members who were experienced with traditional

Fig. 7 Rotating ergonomic PIN VR script display presented in VR

approaches preferred aspects of a familiar approach in a VR script. However, majority of the crew members supported the argument that VR requires new approaches; and the Rotating Cylindrical PIN VR Display was suitable for this form of narrative. While the current display is developed for *Table for Two* PIN VR, display variations in terms of dimensions, ergonomics, fonts and font sizes can be explored for different scripts. To address the issue of longer format scripts, the current display allows the printed material to be replaced with the later scenes. The Display can additionally host pre-production elements such as the timelines and visual storyboards.

6 Future Scope

With advancements in technology, it is recommended that the Rotating Display could be modified into a Smart Screen Cylindrical Display. This display could host a large number of parallel narratives, irrespective of the script length. The navigator could swipe to unfold script continuity. The display can also be presented through a VR Head Mounted Display (HMD) as shown in Fig. 7. This version would allow the navigator to increase or decrease the size as per their convenience.

7 Conclusion

A PIN VR experience presents opportunities to experiment with VR narratives. The experiment validates the use of a Writer's Room for conceptualization, the role of location in a virtual narrative, the effectiveness of a Test Shoot, and the use of colour codes to identify parallel scripts. It is understood that the camera distance and placement can ergonomically affect the emotions of the navigator. The involvement

of street theatre participants confirms the value of street theatre techniques in VR conceptual development. The PIN VR scripts presented in the Traditional Format and Spherical Format have ergonomic limitations of representing parallel timelines. These timelines can be represented with a combination of a Tabular format and a Rotating Cylindrical PIN VR Display. The Tabular format can be handed over to the crew members for portability, while the Rotating Cylindrical PIN VR Display is more efficient in connecting the parallel narratives. The production crew members recommend the utility of the Display for rehearsals and production. While this display is designed for a PIN VR, appropriate modifications can be added in order to experiment with alternative forms of narratives and domains. This study concludes that visual communication ergonomics can be effectively used to communicate a PIN VR script from the director to the VR production crew members through a Rotating Cylindrical PIN VR Display.

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Braking: The Most Strenuous Task of Locomotive Driving

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Abstract Pilots of the Indian Railways are susceptible to high risk of morbidity and low retirement age. This field study suggests these conditions arise from poor cab room configuration design and result in habituation to unsafe postures, which yield psycho-physiological stress on them. The paper evaluates the physical actions in applying the brake, and identifies the WMSD (Work-related musculoskeletal disorders) risks and calls for a modified procedure to ensure safety and pleasure at work. The methodology investigates with 29 male electric-loco pilots of 41.34 ± 5.19 years. A pilot performs several primary functions, including brake application. Rapid Upper Limb Assessment (RULA) was used to evaluate all those driving postures, aiming to identify the probability of musculoskeletal disorders amongst loco pilots. RULA score in breaking actions revealed that about three-quarter of the population require intervention of 'action level-2', and the remaining 'action level-3'. The braking posture worsens gradually over time arising from the magnitude of force required leading to abnormal deviations of postures in legs, wrists, and upper limbs. Few modifications in the braking arrangement including the controls and their configurations and relative action-postures are proposed which *may* subsequently reduce the RULA scores and correction demands to offer more crew friendly braking actions. Considering the momentum of the loaded goods train of about 58 wagons plus the electric-loco is not a pleasant task till date.

Keywords Braking actions · Electric goods-train · Loco-pilots · RULA · Ergonomic assessment

1 Introduction

Indian Railways is a national asset working under the single control of the 'Ministry of Railways'. It is one of the largest rail networks in the world. By connecting far

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corners of the country, it acts as the lifeline for Indian citizens and fuels the Indian economy. Loco-Pilots play a vital role in railway transport system, as millions of passengers and million tons of freight moves daily and safely due to the effort of those categories, working round the clock [1]. The train driving is directly linked to two things, design of the vehicle and environment. Therefore the interior of the cab need to be designed in the appropriate manner to ensure safety, efficiency and comfort in driving [2]. The working environment of drivers' cabin is the main contributing factor for physical load on drivers. Improvement on those aspects will certainly increase safety in driving [3]. During diagnosis the driver's cabin of the electric locomotive, man or machine were not treated separately, as because these two has mutual interrelations [4]. A multivariate human model was useful to assess control locations of train cab design [5]. Work-related musculoskeletal disorders (MSDs) are highly associated with improper design of workstation and poorly adopted postures [6]. Improper design of bus cabin may causes physical strain on drivers, results moderate level of risk as suggested by RULA [7]. RULA revealed that nearly half of the population is at high risk level for developing WMSDs due to unsafe posture during driving bus [8]. Compared to other types of job, bus driving is more stressful as RULA score suggest, and stretching exercise had advantageous effect to treat those musculoskeletal symptoms and to reduce body pain [9]. Professional truck drivers are susceptible to high morbidity rate and low retirement age [10]. The improvement of working life of loco pilots is directly correlated to the productivity, for growth and safety of Indian Railways [11].

The objective of present study is to evaluate the braking activity of loco pilots in the action of driving a train by using established method of physical posture analysis tool with a view to identify the tasks inducing the highest potential of risk inflicting the musculoskeletal disorder. To propose a design modification of loco driver cabin plan from physical perspective to ensure safety and pleasure at work.

2 Methodology

Four different types of electric locomotives are used in Indian Railways to haul goods train, on which WAG_7 (Wide/broad gauge, Alternating current, Goods traffic, 7th generation/model) Old Variant locomotives were only considered for study. It is one of the most successful variant of indigenous locomotive built by CLW (Chittaranjan Locomotive Works) and BHEL (Bharat Heavy Electricals Limited), to RDSO (Research Designs & Standards Organisation) specifications. The size of the engine's cab room is quite small, therefore the driving posture is often constrained. The elevation of A-9 valve, which is used to energize the braking system, is higher than the top of the driving desk and situated on the left side. The locations of brake paddle, which is also required to operate simultaneously during braking, is situated in a quite awkward place, and need to be pressed by right leg only.

About 29 male electric loco pilots with mean age of 41.34 and SD $\pm$ 5.19 years, belongs to Kharagpur Division of South Eastern Railway, were considered as the

subjects. Their main function is to drive various types of electric goods locomotives with or without loaded and/or empty wagons. To understand the elementary activities performed by the loco pilots during actual driving and to collect the raw postural data in situ, the author accompanied the loco pilots during their duty hours. The postural data on driving stance were recorded video-graphically. A compact digital camera was used to record all the action-movements in photographs and videos.

The observation indicates that the loco pilots perform few basic primary activities, essential to operate the locomotive, including brake application. The present study focuses on the body postures mentioned above only.

For selecting loco pilots, voluntary participation was used. First, the purpose of the study was explained to each and every participating loco pilot, and the field survey was conducted then after.

The total task, comprising the work-elements, those identify the total WMSD of brake application as an activity comprises (a) positioning the body to take the right leg to the appropriate location, and (b) when the left hand as well is concurrently engaged. It is executed to slowdown the speed of the train, or to stop it. In this joint action (c) the left hand operates the A-9 valve lever, and (d) the right leg pushes the brake-switch to release the brake of locomotive, such that the dedicated brakes will only operate in the trailing wagons. This total activity (a + b + c + d) closely depends further, as some other associated cognitive tasks, on (i) the railway traffic signals, (ii) zonal speed-restriction at certain regions of the track, and (iii) as the situation demands. The adopted posture for braking is quite awkward. It has also been considered that to operate the A-9 lever, (iv) about 3.5 kgf force is required; this however is as per opinion of the loco inspectors. Whereas, (v) the brake foot switch require only very nominal force below 1 kgf to operate it.

For the present study, Rapid Upper Limb Assessment (RULA) [12] was used to evaluate the driving postures, aiming to identify the probability of musculoskeletal disorders in loco pilots. The RULA method provides an easy and convenient rating tool to gauge work related musculoskeletal loads on neck and upper-limb region. It is used to assess the posture, force, and movement associated with sedentary work. This rating tool further provides a single score for a 'snapshot' task, which rates as a set of posture, force, and movement required. The risk is calculated by a score ranging from 1 (low) to 7 (high), which are grouped into four action levels with an indication of time frame for expected risk control initiation.

3 Results

The details of RULA scoring during brake application in WAG_7 (OV) Locomotive and the suggested action level are provided in Table 1 and Figs. 1 and 2.

During brake application 21 persons out of 29 is having action level of 2. The remaining 8 population is belonging to action level 3.

Table 1 RULA scores during brake application in WAG_7 (OV) locomotive

Score	Posture score A	Wrist and ARM score	Posture score B	Neck, trunk and leg score	Rula score (Nos.)	Action level	Total population (Nos.)
1	0	0	1	1	0	1	0
2	4	0	0	0	0		
3	7	4	28	28	11	2	21
4	10	7	0	0	10		
5	8	10	0	0	8	3	8
6	0	8	0	0	0		
Mode	4	5	3	3	3	–	2

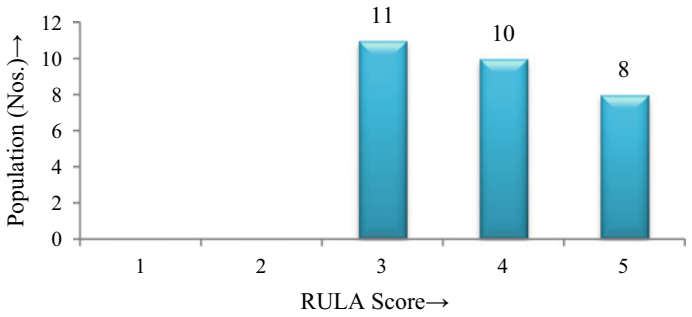

Fig. 1 Graphical representation of RULA score during brake application in WAG_7 (OV) locomotive

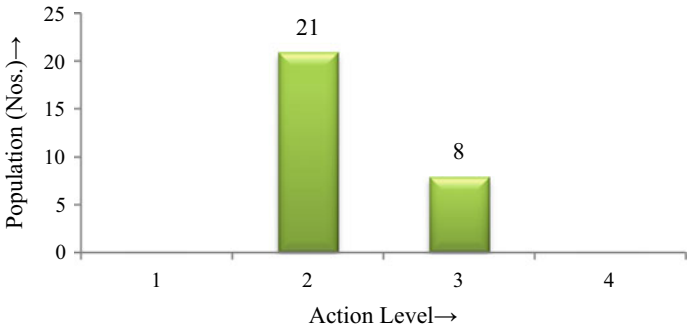

Fig. 2 Graphical representation of priority for change as suggested by RULA

The elaboration of action level indicates that the final RULA score is three for 11 numbers of loco pilots, ten belongs to RULA score 4 and remaining eight having RULA score 5.

Further elaboration of RULA scoring system indicate that the total population having 2 to 5 "Posture Score A", with a mode value at 4. The same score is shifted to one score high for "Wrist & Arm Score", with a mode value of 5.

For "Posture Score B", the lion's share, i.e. 28 out of 29 loco pilots, lying on mark 3, and there is no observable shifting of "neck, Trunk & Leg Score" was found.

4 Discussion

RULA suggests, during application of the brake, the total population is divided between action-level of '2' and '3', it means proper ergonomic intervention is required. The elaboration of RULA scoring system indicates that the posture score—A for entire population varies between '2' to '5'. This might generate from awkward posture of the upper limb. The score is pushed up by one due to addition of the force/load to be applied. Similarly due to awkward lower limb posture, the score—B lies at '3'. Ultimately, these two together push up the RULA score. It is suggested that relocating and reorienting the brake valve, the upper limb postural difficulties can be reduced. Also, positions of the foot switches need to be relocated. By reducing the extent of force required to operate the brake lever can improve the situation.

In total, the WMSD postures in braking action are found to worsen for the collective and simultaneous presence of (i) poor leg postures, (ii) poor wrist orientation, (iii) upper limb postures, and (iv) the magnitude of force requirement as indicated by RULA search.

For betterment of driving arrangement and there by postures, the following modifications were proposed.

1. Instead of horizontally operated brake lever, vertically operated brake lever can improve the effort score by preventing wrist deviation. The 90° rotation of A – 9 and SA – 9 valves are quite feasible with existing scenario and such arrangement is shown in Fig. 3. It may also to be noted that the valves need to be reconfigured for its location nearer to the driving desk so that the abduction of the posture can be prevented.
2. The force required to operate the brake lever needs to be brought down below 1 kg.
3. An existing driving arrangement in WAG_7 (OV) locomotive is shown in Fig. 4a. A platform of 2–3 inch height is suggested to be provided on the same and the brake foot-switch needs to be re-located exactly at the same height in front of the said platform. It will prevent the loco pilot to adopt any inconvenient posture during operating the same. The arrangement of the same is shown in Fig. 4b.
4. By showing video tapes of the individual loco pilots (and comparing them with a soft-warred postural training model driven during driving), the stressful habits in driving actions can be corrected.

The proper adaptation of proposed arrangement will certainly bring down the RULA posture score below the danger mark during braking. An experimental setup

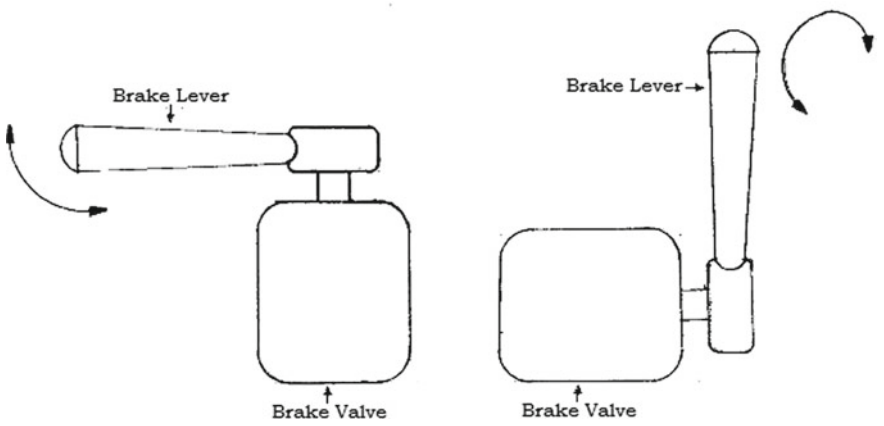

Fig. 3 Existing and proposed brake arrangement respectively

was made in the railway loco shed and applied on a single loco pilot to test the efficacy of the proposition. In an ideal experimental condition, the elaboration of RULA scoring system is as follows –

1. Upper arm score is 2 – 1 = 1, as arm is supported.
2. Lower arm score is 1,
3. Wrist score is 2 + 1 = 3, as wrist bent from mid-line,
4. Wrist twist score is 1.

Therefore, posture A score is 2. As the muscle use score and force/load score is 0, so, the wrist and arm score is 2, indicating that no shifting of score occurs upward.

1. Neck position score is 1,
2. Trunk position score is 1,
3. Leg score is 1.

Therefore, posture score B is 1. As the muscle use score and force/load score is 0, so, the neck, trunk and leg score is 1, indicating that no deviation in the score is again observed. Finally, the above two score yield RULA score of 2, which belongs to action level 1, suggesting that the posture is acceptable and quite below the earlier results; hence lie within acceptable limits. However, these score may somewhat deviate at the times, as a limitation of the study so conducted.

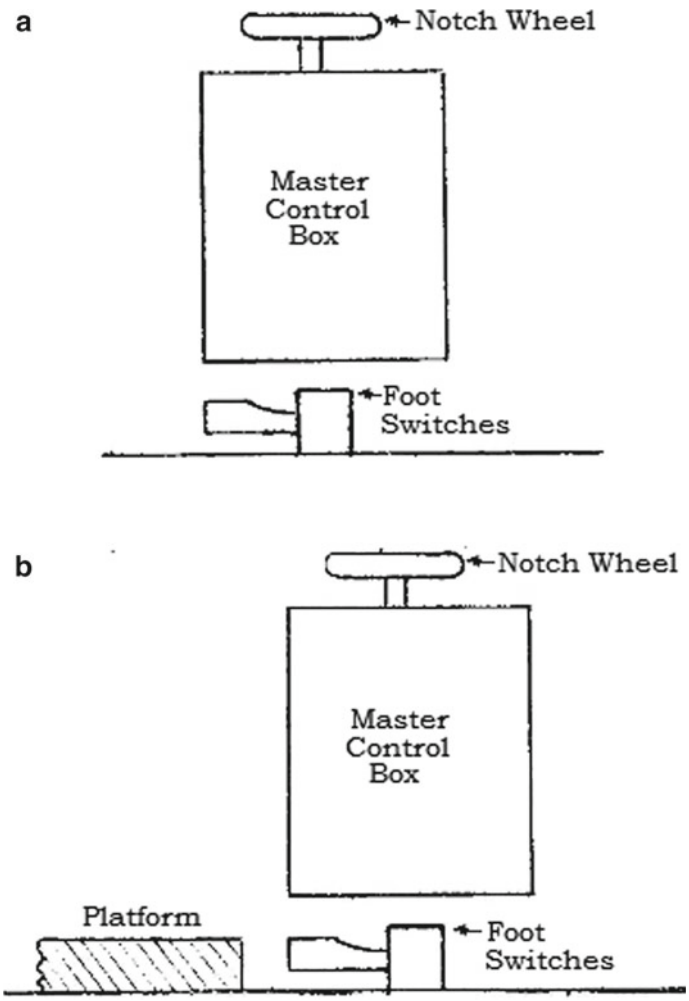

Fig. 4 **a** Existing driving arrangement. **b** Proposed driving arrangement

5 Conclusion

Loco pilots are the heart of Indian Railways, but the duties are highly stressful on psycho-physiological viewpoint. As the braking of electric goods locomotive is not a pleasant task till date, therefore in-depth investigations have been carried out with a view to explore the possibility to improve the working conditions. Within the constraints of the permission, following technical protocols, to be granted by the respective technical authority, the following conclusions may be drawn.

By the motion analysis of various tasks during different physical activities it was observed that the braking is the most troublesome task, causing strain on both

upper and lower limb regions. Therefore, design change on controls is proposed, and adaptation of correct driving postures is recommended from ergonomics viewpoint.

Based upon the present status of Indian Railway it is neither feasible to discard the existing driver cabin nor possible to carry out a total alteration work. Under these above scenarios, few innovative, easy to implement, economic but very much effective modification in the existing cab room has been proposed. To tackle the WMSD, a new but effective working envelope was proposed, where minute modifications are made on brake lever, and on brake pedal. Details strategy planning has been recommended with a view to promote awareness and training.

Still there is lot of future research scope in this respect particularly the practical implementation of the modification as proposed on this study and investigation further on the same direction is quite possible to evaluate the outcome of the modifications. The whole body vibration (WBV) is another aspect of study, which was not focused here, but a vital issue for future research.

The overall expected benefit from the present research study is that the working ambience will be more crew friendly with less probability of work related musculoskeletal disorder and thereby promote a more ergonomic driver friendly working environment. It is quite evident that this will help the driver to cater better service more efficiently in the long run and that will have a tremendous impact on safety security and overall welfare of the Indian railways.

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Impact of Writing Tools in the Evolution of Telugu Script

Chakradhar Aalla and Mohammad Shahid

Abstract The paper brings to focus, the role of the writing tools and writing medium on the evolution of the Telugu script from Brahmi script. It also correlates with the time period of the script transformation. The information on the Telugu script from the published works of prominent historians and linguists was studied. Then the data collected from various sources such as manuscripts, inscriptions, and library archives were analyzed and presented. The evolution of the Telugu script reaches a pinnacle by the end of the twentieth century AD, thanks to the standardization process that is necessary for a print-oriented mass modern society. However, due to the creative demands of the advertising and book publishing industry, the artistic dimension of the script found expression. The paper lays special emphasis on the impact of ergonomics of the Ghantam (metallic stylus) and the tool interaction on the Tadipatra (processed palm-leaf writing surface) and its influence on the rectilinear and curvilinear letterforms.

Keywords Telugu script · Writing tools · Human factors · Letterform evolution

1 Introduction

Telugu script is mainly used to visually represent the Telugu language. It is evolved from the Ashokan Brahmi script, which was used in the southern region of the Indian subcontinent during the second century AD. The sophistication and stylization of the script occurred from the eleventh century AD in the later phase of the script development. And during the thirteenth century AD (also referred to as the Ketana period), the script developed a distinctive visual character from the earlier Telugu-Kannada script. During the period from third century BC to the seventeenth century AD, the impact of the writing medium especially the palm leaf played a pivotal role in letterform evolution.

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Telugu script, which follows the 'what you see is what you get' format, is considered very scientific by the linguists because it uses a set of basic symbols and modifiers, and constriction of compound alphabet follow a definite set of rules and procedures. The soundness of the script can be observed with the ease in which the sounds and their corresponding visual symbol representations are identified. The script has 18 vowel symbols, 36 consonant symbols, and 3 dual symbols. It may visually represent the phonetic spectrum of almost all Indian and most of the world languages.

2 Telugu Script Transformation

2.1 Writing Medium and Tools

For this study, the term writing tools includes both the writing medium as well as the marking tool. The history of linguistic scripts in India followed a different line from that of the languages themselves [1]. The writing tools, mediums and conventions followed during the development of the Telugu language had their influence on the Telugu Script. But, since languages evolve and diffuse more vigorously than their visual representations, the script transforms more gradually over a period.

Stone and Metal Inscriptions. These are the earliest form of evidence available to study the development of the scripts. Typically, two types of stones were used in the region, Marble and Granite. The inscriptions made on Granite took more effort and skill of the craftsman to execute than the Marble inscriptions due to the hardness of the material. The Chisel and Mallet (Fig. 1) also play a significant role in the transformation of the early script. The early use of metal mallets on a metal chisel gave the robust geometrical form (Fig. 2) to the early Brahmi derivatives whereas,

Fig. 1 Stone inscription tools—various sized metal chisels used with wooden mallets

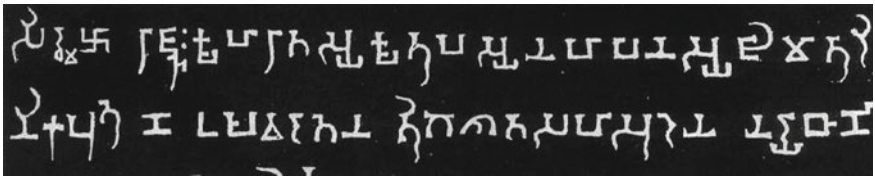

Fig. 2 Stone inscription of shatavahana period—first century AD

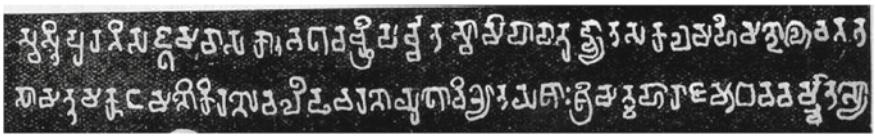

Fig. 3 Stone Inscription of Vishnukundi Indraverma—sixth century AD

the subsequent use of wooden mallets and copper plates allowed the craftsman to explore curvilinear form and visual accents to the letterforms (Fig. 3).

Palm Leaf Manuscript. It is the main medium for calligraphy and art in Southern Asia and Southeast Asian Countries. It is one of the earliest writing mediums used even in India, as well as in the southern region [2]. The origin of this medium is still not very established, even though its use is quite prevalent. Agrawal ascertains that it is difficult to say exactly when the palm-leaf first began to be used for writing. There are no extant palm leaf manuscripts in India before the tenth century. However, the palm leaf was in use much earlier, since it is mentioned as a writing material in several literary works and its depiction can be seen in several sculptures and monuments [2].

Paper and Printing. Even though the paper was in use in the Telugu region from the fourteenth century AD, palm-leaf manuscripts remained the preferred medium of writing till the late eighteenth century. And in the nineteenth century, Christian missionaries entered India and they were required to print the Bible and other religious books in local languages. There was a dire need for dictionaries and grammar books in the Indian Languages. Then came the colonial powers to establish their colonies in India. The civil servants were required to learn the local languages for efficient administrative performance. Out of this necessity, the missionaries and the colonial powers started printing in India in few local languages using vernacular scripts.

The printing technology needed a standard version of the script to be used. And the movable metal typesetting had its share of constraints to follow. The inspiration for designing the Telugu typefaces for the printing press was the manuscripts of the sixteenth century. It is interesting to note that, printing was started in South India in the sixteenth century AD itself, whereas in North India, it took another two centuries for the same. Hence, it is safe to assume that the script reached its highest refinement and maturity during the manuscript era (Fig. 4).

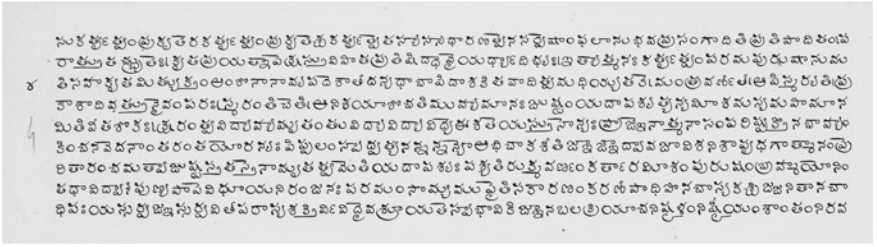

Fig. 4 An Inscription of fifteenth century AD—the letterforms were refined and almost similar to the standardized Telugu script used for writing and printing

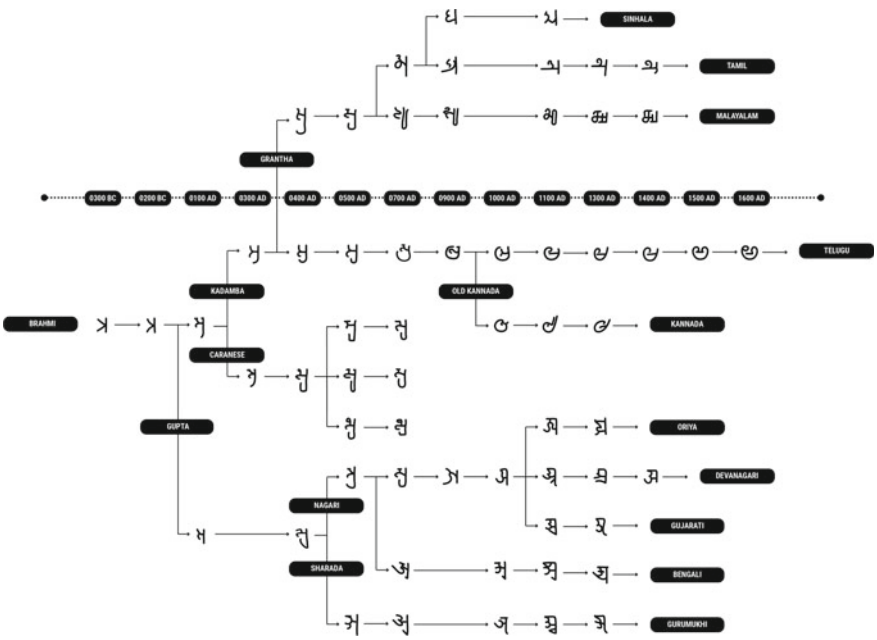

Fig. 5 An infographic showing Brahmi script family evolution from 300 BC to 1600 AD

2.2 Historical Perspective

Telugu script has been introduced to the Deccan and coastal regions of South India by the Shatavahana dynasty. While the script descended from the Brahmi script family (Fig. 5), most of the southern Indian languages evolved from the Proto-Dravidian language of the Indus Valley [3]. The similarities between the Telugu script and the other Indian scripts, including the Devanagari becomes very evident upon careful observation (Fig. 5).

Early Phase. The earliest Telugu inscription which is currently available dates back to the sixth Century AD. This inscription contains few Telugu sentences and belongs to Chola dynasty. The region of Telugu Nadu (which is the present-day Telangana and Andhra Pradesh region) and Karri Nadu (which is the present-day Karnataka region) were administered by common rulers for over 2000 years and they were patronizing both languages. This is the major factor for the scripts of both these regions, namely Telugu and Kannada to bear great visual connect, even though the languages themselves differ from each other to a great extent.

Medieval Phase. The spread of the Kakatiya Empire in the Telugu Nadu region from the twelfth century AD to fourteenth century AD marks the golden era for the Telugu language and script. The Vijayanagara Empire of South India, which is considered one of the finest empires by some historians, patronized arts and literature in all the 4 southern states. This period from fourteenth to sixteenth century AD, with a several scribes working on many literary documents, helped the Telugu script to undergo a process of refinement.

Contemporary Phase. The British rule during the nineteenth and twentieth centuries and the establishment of the Christian missionaries in India along with the influence of the English language and the access of the printing technology had a huge impact on the propagation of the Telugu letterform in popular mediums. The newspaper and the magazine industry from the 1930s with various printing techniques also helped the Telugu letterform undergo artistic and creative experimentation. And, the contemporary era, from the 1980s with the introduction and the spread of the digital media with various typesetting and type design tools opened the doors for further exploration of the creative opportunities using the letterform.

3 Palm Leaf and Telugu Script

In the evolution of the art of writing, script, and language, the palm is an invaluable source because it codifies and preserves human expression. Even though the Indian scribes have used palm leaves as a writing medium for millennia, the thousands of the available artifacts in various museums and libraries belong to only past 400–500 years. Because the average time the material can be preserved, even with the finest curing techniques was only four of five centuries, after which the scribes were commissioned to re-write crucial information and knowledge on newly cured palm leaves.

3.1 Type of Palm Leaves Used for Writing Telugu Script

Of the more than 2400 species of palms distributed worldwide, three species have been identified as commonly used in palm leaf manuscripts.

Borassus Flabellifer Linn. This variety is referred to as the Palmyra palm and they naturally grow in the dry and arid climates. This variety has less durability as it is prone to pests. This is a stronger and thicker variety. Although the leaves are robust and malleable initially, they turn brittle with time.

Corypha Umbraculifera Linn. This variety is referred to as the Talipot or Fan palm. This variety needs moisture and precipitation for its growth. It is widely available in coastal regions of southern India. The texture of the leaf is soft and mildly coloured making them a legible writing medium. These leaves remain flexible even they are dried and remain in that state for an extended duration of time, making it the most durable type of palm leaf. For these reasons, it is not surprised to note that the earliest available specimens of the manuscripts are of this variety.

Corypha Taliera. This is the most robust variety of the palm when harvested. The leaves are thick, brittle, and prone to pests. They have a brown hue with dark coloured spines. They have the least durability among the 3 types as they break very easily when dry.

According to Cornell University Library, the most frequently used manuscript leaves come from the Palmyra and Talipot palms. The most preferred of these 3 types of palm in India was the Talipot palm as its leaves offer much-needed suppleness and durability. The administrative and cultural centers for the Telugu region were situated in arid regions of the Deccan plateau which had very little access to the flexible and durable Talipot palm.

3.2 Cultural Significance of Palm Leaf Manuscripts

Palm Leaf Manuscripts played an important role in the development of South Asian cultural knowledge and religious practice. In South Asia, around the first century BC, there was a shift in the way cultural knowledge was disseminated, from orally to written accounts, first in stone, then on palm leaves, and finally on paper [4]. Thus, for around two millennia, manuscripts, and particularly Palm Leaf manuscripts, were the main way of knowledge transmission.

Richard Salomon, a prominent Indian epigraphist, ascertains the use of palm leaf manuscripts and few other mediums in his work. He suggests that, before the Ashokan period, the use of this medium was exclusively for administrative and economic book-keeping. Also, delicate materials like palm leaf cannot endure the extremes of the Indian climate. Hence, he ascertains that, the absence of the evidence from these earlier times does not necessarily point out the non-existence of these materials [5].

3.3 Social Impact of Palm Leaf Manuscripts

In India, the use of palm-leaf manuscript was the main medium for recording and exchanging information until the era of printing. This was referred as the Palm leaf manuscript culture by some epigraphists. The medieval manuscript culture mainly focuses on the transition of palm leaf as a medium in religious institutions and royal courts to the everyday market, with access to various social groups. This era has created new occupations which entered around the manuscripts, such as preparing, scribing, and the trade of palm leaves.

The later phase of the palm leaf manuscript occurred preceding the introduction of the printing press. This era also extends beyond the rise of printing technology, the main reason for this being the cultural prominence this writing medium has garnered. As, it was a more durable and convenient medium compared to paper, there was a desire among the practitioners for standardization and uniformity of the script. It was also a more durable and convenient medium compared to paper. This phase has truly democratised the use of palm-leaf manuscripts, as the process of making, copying, and sourcing involved people from various strata of the society.

Thus, any compartmentalization of palm leaf manuscript writing is not borne out of ethnographic data or the evidence from colophons of surviving manuscripts. Instead, a far more complex picture emerges by a comparison of these with earlier literary records. Adequate attention must be paid to the production and writing procedure of palm leaf manuscripts and the involvement of scribes for a comprehensive understanding of the subject.

3.4 Impact of Palm Leaf on Manuscript Design

The natural attributes of the palm leaf are pivotal for the unique features of the Indian manuscript. The form factor of the book itself follows the shape of the trimmed leaf. The leaf dictates the design and layout constraints of the text and images. The grain of the leaf and the texture impacts the binding style and adhesion. The media interaction with the leaf determines the script direction, collation, and orientation. The preservation of the artifact and the conservation challenges the specimens pose are due to the fact that the natural material like a leaf deteriorates with time.

Palm leaves are processed through various techniques to make them fit for scribing. Traditionally, people followed a lengthy process to make them smooth and durable for preservation. In this regard M.M. Chakravarty, a British colonial official at Jaipur in the nineteenth century has given an account of the preparation of palm-leaf manuscript. He has mentioned that palm leaves of three to four months old are collected for processing. Then they were processed through three techniques known as Balikasa (curing with cow dung), Haldikasa (curing with turmeric water), and Amani (curing with rice water). The types of processing and curing of the palm leaf

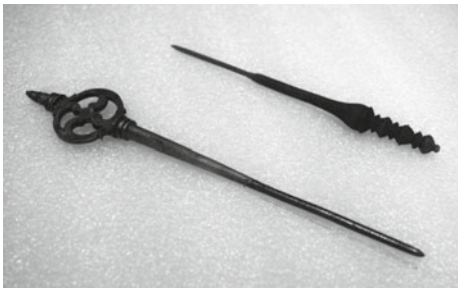

Fig. 6 Single and double-pointed iron stylus produced in different sizes based on requirement of the scribe

differed greatly from one climatic region to another and is also dependent on the type of palm leaf chosen.

4 Human Factors and Ergonomics

4.1 The Ghantam Stylus and Writing Process

The instrument through which the letters are scratched on the palm leaf is known as stylus or Lekhani, which has a sharp steel point. The tip of the stylus is sharpened with the help of an oiled stone. The length of a stylus varies from eight to twenty inches and is produced by the specialized blacksmith as per the requirement of the scribe. One of its ends is pointed and the other is in the shape of half leaf, which is used to cut the palm leaf to the required size.

The part of the rod, where the fingers are set to write on the leaf, is made a bit thicker to provide a better grip. There were some styluses with two writing ends, called Domuna or double-pointed (Fig. 6). In South India, three varieties of the stylus are used, according to the shape of the upper end, i.e. sharp-pointed, knife-shaped and ear-shaped.

4.2 Variations in Stylus Usage

A great deal of instruction and practice is essential for writing or palm leaf [6]. The scribe often requires professional training of a decade or two just to learn the etching process. Some scribes specialise in illustration and drawing which requires use of a finer tipped stylus and a great amount of dexterity [7].

According to the Ph.D. thesis of Dr. P Perumal, a retired conservator of Saraswati Mahal Library, Thanjavur, there were differences in the use of the stylus in southern India. The Malayalam and Oriya manuscripts were inscribes taking the left them as a support/guide, whereas, in Tamil Nadu, the thumb was used as a fulcrum (Fig. 7).

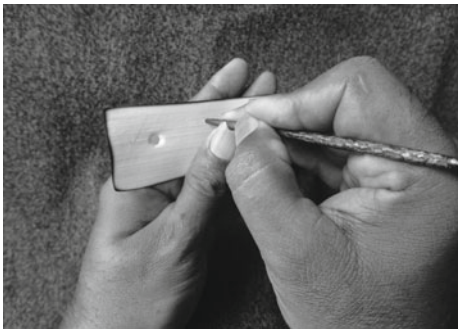

Fig. 7 A craftsman demonstrating the writing posture using the grove on the thumb—this practice is particularly prevalent to inscribe Tamil letterforms—the size, shape, spacing between letters and lines were determined by the movement of the thumb

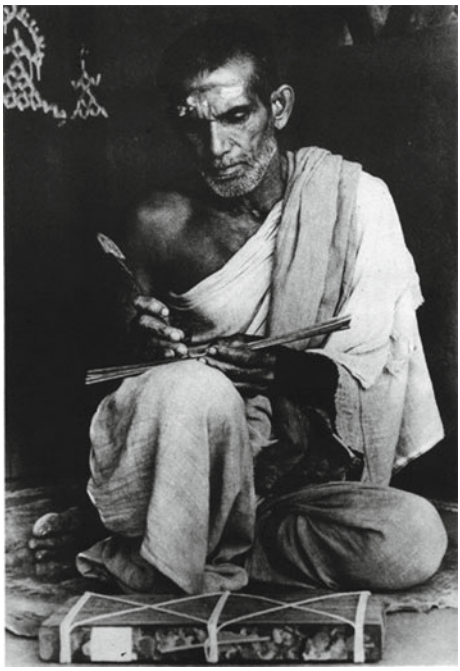

Fig. 8 A skilled craftsman working on the palm leaf—using freehand style and a sharper stylus without the help of the thumb

The manuscripts which were written in Telugu and Kannada scripts were inscribed holding the stylus in the fist and following a freehand approach (Fig. 8).

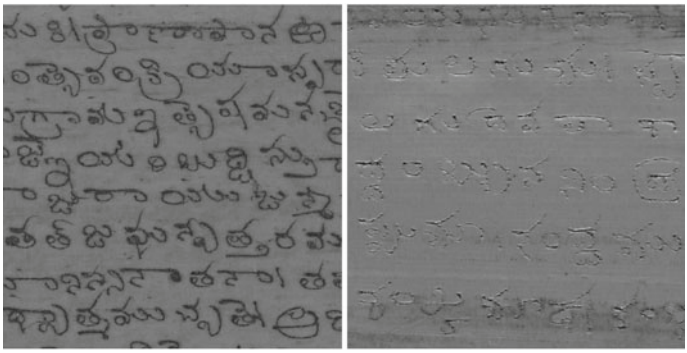

Fig. 9 A picture showing the procedure of etching palm leaf—It is to be observed that the horizontal lines in the Telugu manuscripts do not adhere to the guideline—suggesting the freedom from using the left-hand thumb as a fulcrum

4.3 Biomechanics

The biomechanics of the scribe's fingers, hand, and elbow plays a significant role in the basic form of the letters. The variations in the scribes' posture and writing style provide various degrees of freedom and constraints in the movement of the hand and arm (Fig. 9). For the usage in the Telugu script, the stylus used to be held in the palm and the circular motion of the wrist and the elbow largely dictated the form of the letters. Also, the use of elbow movement gives lesser muscular fatigue in the hands and shoulders [8].

Hence, a calligraphic artefact is not an end in itself. They lend themselves as source material to start an explorative study and analysis of writing tradition as part of the culture. The available specimens from the earlier times, mainly stone and metal inscriptions point out this cultural phenomenon in the Telugu region [9].

5 Conclusions

Various factors contributed to the evolution of the Telugu script:

1. The usage of finer tools during the later stone inscriptions paved a path for the development of slight curvilinear forms of Kadamba and Grantha scripts (Fig. 5).
2. The production and availability of the Palmyra Palm trees, which are slightly thicker and dry than the fan palm in the Deccan plateau region, where the major development of Telugu script may have contributed to the sturdier writing posture using the fist (see Fig. 8).
3. The fibrous texture and the Palmyra palm dictated the use of round letterforms to avoid flaking and tear of the leaf.
4. The freehand style of using the stylus (Ghantam) without the use of the thumb as a support or the fulcrum gave the script a vertical three-tier structure, where the words extend below and above the x-height (see Fig. 4).
5. The social and cultural implications of using Palm leaf as a writing medium and the Ghantam stylus as the writing tool in creating new avenues of specialization and involvement of various groups has the biggest impact on both the human physiology and psychology of local scribes and craftsmen.
6. The prevalence of the use of manuscripts as a preferred mode of record making till the end of the sixteenth century made the script adopt the same letterform features to use on paper and later typeface design of the printing press (see Fig. 4). Thus, it is safe to assume that the most crucial changes to the Telugu Script occurred in the hand of the scribes during the sixth century AD to the seventeenth century AD (see Fig. 10).
7. Human factors such as the dexterity of the scribe and the biomechanics of the scribe's wrists and elbow played a crucial role in determining the form of the script.

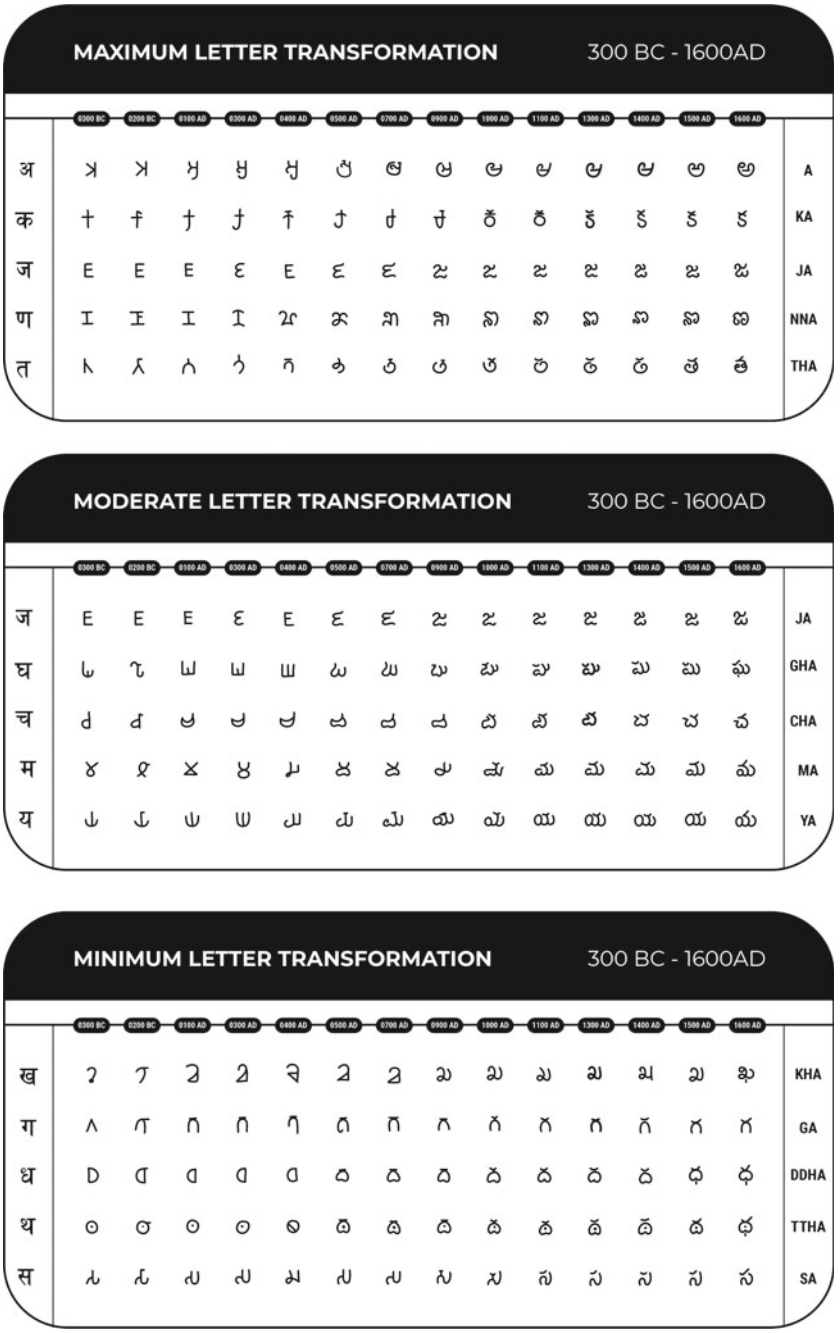

Fig. 10 Comparison of the letterforms transformation—the angular letterforms have undergone maximum change compared to the curvilinear—suggesting the impact of the scribing process on letterform evolution

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Exploring Pedagogical Influence and Cognitive Learning on Children by Implementing Innovative Instructional Design Methodology for Learning English Alphabet Writing from Drawing

Abhay Verma and Abhijit Padun

Abstract The foundational process of learning that starts in our life at the very early stage help create a lifelong influence on us throughout our entire life. Therefore pedagogical influence on children in the kindergarten level is the most crucial stage as they start learning things very quickly at their early age. In the foundational stages, children learn how to read and write as per the instructors' directions, where the teaching approach of the instructor plays an important role in guiding and making children comprehend the information. Hence, instructions designed specifically on a particular subject for the children of the kindergarten stage carry solemn responsibility to nurture preliminary knowledge in them. This study carried out an innovative experiment where the method describes the technique of learning the English alphabet system by drawing a figure from letters and vice versa with easy-to-follow steps which have made the learning and teaching process more fluent. The objective of the experiment was to make children learn the English alphabet system by following a methodology that shows writing of a letter by resembling it with an object, and how to draw that object from that particular letter in very easy-to-follow steps. The study has aimed to nurture the creative and cognitive side of a child by teaching them observation and drawing while building a strong foundation of the English language. Further, the study has also aimed to deliver a complete book with step-by-step instructions which could be useful for the instructors teaching in kindergarten schools.

Keywords Pedagogical activity · Instructional design for children · English learning methodology · Cognitive English learning for children

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1 Introduction

In the development years, children notice the things which an adult will not because of their extraordinary observation skills, which also shows the desire to know, gather information, and make themselves increasingly familiar with the unfamiliarity surrounding them [1]. According to Leonard Bloomfield [2], "Each Community is formed by the activity of language." The existence of human life can be possible without language, but the transmission and exchange of ideas won't be possible, which will affect the social order, and the smooth functioning of the society is unimaginable. Globalization made it very important for people to communicate and collaborate effectively, English being the most spoken and comprehended language in the world, the young generation of children needs to have a good grasp of this language.

From an ergonomic and user experience standpoint, the books that are used to teach the English language to the children in their primary grade level, follow a very similar pattern where a letter is associated with an object to make them learn the whole alphabet system gradually.

In the later stages teaching a technique to skillfully tie up the individual letters for the word-formation becomes difficult for the teaching, and the learning process would be tedious and unexciting. Hence, it can be said that learning the English alphabet system is the most important stage of the overall process of learning the language.

It has been observed that the existing teaching technique focuses on making children 'Remember' rather than 'Understanding' of the concept. The current teaching methodology is based on, non-resemblance of the shape of the letterforms with that of the supportive illustrations [3]. This research article tries to solve this ergonomic problem by presenting a methodology by designing and reimagining the existing adapted methodology for the systematic teaching and learning process of the language. Also, this study aims to have a better understanding of pedagogical development and cognitive learning within the context of learning the English language.

2 Background Study

Fundamentally there are two types of English learners, the ones who learn it as their first language and the others who learn it as their second or maybe third language. The maximum number of English speakers come from the United States of America followed by other countries such as India, Pakistan, Philippines, and the United Kingdom [4]. For both kinds of learners, English is taught in their schools formally in the classroom setting. In the classroom setting the children are taught all of the technical aspects of the language. In this context, the technical aspects refer to alphabet writing, word composition, sentence composition, English grammar, etc.

Children who are learning English as their second language, first think of the sentence/word in the first language and then draft the whole sentence/word in the second language [5]. This cognitive conversion process obviously makes the learning process more difficult compared to the children who are learning English as their first language.

It has been observed that interestingly children from primary grade are intensively inclined towards the pictures presented to support the story of their storybooks. Post observing the pictures, if explicitly taught a kid will go towards the plot of the story, and, finally, they'll give effort in reading all of the text provided [1]. This discussion clearly shows the inclination of the children towards the supportive visuals more than the text. Hence the attention towards crafting meaningful and logical illustrations could improve the user experience and it plays a major role in understanding the language/context to the optimum level of achieving understanding, accuracy, and fluency on the language/context.

2.1 Need Identification

The language acquisition process happens in a very organic and natural way when the children are involved in learning the language deeply, interacting subconsciously, and reacting spontaneously. Contrary language learning is a conscious process that usually happens in a specific programmed way, where instructions are given by the teacher to the children of primary grade school [6]. The overall learning process, user experience, and at minimum the first stage of learning the alphabet system should be very effortless and the path of least resistance for the children to be able to take interest and flourish their creativity.

3 Literature Review

3.1 Significance of the Semantic Typography and Its Cognitive Assessment

Originally this concept was formed more than 20 years ago by a Korean designer Ji Lee, who is responsible for initiating a design project in which his students were required to see the letterforms beyond their dull and practical aspects. Semantic typography is a wordmark representation technique in which the meaning of the word is represented by the combined letterforms of the word itself. However, the use of semantic typography can also be successfully expanded to craft individual letterforms for teaching the English language to the children of primary grade schools as well [3].

3.2 Difficulties in Learning and Teaching the English Language

In the context of children who are learning English as their second language a descriptive survey data with a sample size of 144 teachers and 288 students shows that 75.6% of students face some kind of difficulties while interacting in English with their teachers and classmates [7]. It can be considered that there is a gap in the teaching methodology followed by the teachers to teach the language because out of 288 students 71.8% agreed that their English teacher taught them English 'as a subject rather than a language [7]. Upon further investigation, it was found that 60.1% of students stated that English is difficult to learn compared to the other languages [7]. Similarly, children who are learning English as a first language use the alphabet teaching books, the methodology of which is very similar to the ones uses by the children who are acquiring English as a first language.

This learning gap can be addressed by conducting an ergonomic design experiment where alphabet learning and teaching can be approached in an entirely different way. In the new approach, there should be a substantial connection between the letter and the associated imagery/illustrations so that it becomes easy for the children to grasp the information.

4 Aim and Objective

Aim

To design an ergonomic instructional English alphabet teaching methodology based on semantic typography to explore the pedagogical influence and cognitive learning on children.

Objective

- Analyzing the commonly available and used textbooks for teaching the English alphabet to the children of the primary grade in India.
- To gather quantitative and qualitative information on ergonomic challenges faced by the children while learning the English language.
- Understand and study the psychological and creative process of learning English as and first and second language.
- To design a learning and teaching methodology by exploring the combination of Instructional design and Semantic typography.
- Test the degree of the feasibility of the experiment by conducting the survey amongst primary grade students.

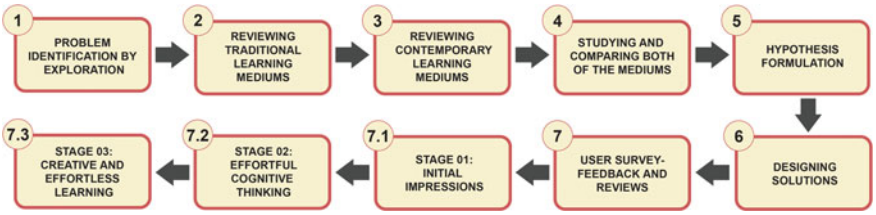

Fig. 1 Schematic representation of the proposed methodology

5 Methodology

Seven step methodology has been followed as shown in Fig. 1 to explore the research area and design a feasible solution for teaching the English alphabet to the children.

5.1 Exploring Research Area for Problem Identification

This is stage is concerned with the problem identification where Indian English medium schools were visited and the qualitative data analysis based on the observations of the teaching process was done. One of most key teaching and curriculum factors that were observed is that, all of the Indian schools have been following approximately the same structure of teaching. However, a significant difference was observed in the tonality and the body language of the teacher. Non-verbal communication plays a very crucial role in delivering a lot of cues to the students, eye movement, physical movement, and tall waking posture communicate the degree of subject or topic significance [6].

Around 40 primary grade students were chosen to conduct an initial survey for better understanding of the problem statement. To maintain the expressiveness and unbiased opinion the survey was conducted without the presence of the teacher upon their approval. The asked questions were based on the current teaching process, interest in the subject and other difficulties of learning the subject.

From the survey it was found out that the current teaching process in which an English letter is being associated with an object, lacks interesting procedural steps towards the development of the creative solution. Eventually, the learning process becomes complicated for the children, and their interest falls down gradually. Along with the body language, the subject should be interesting enough for the teacher and the students as well. The problem demanded a solution that can examine the ergonomic aspects of learning a new language to eventually improve the user experience, which is getting in the way of the English language acquisition process for the kids.

Fig. 2 Sample of books used for teaching English alphabet to the children

5.2 Reviewing Traditional Learning Mediums

After identifying the problem, exploration and collection of the English alphabet learning books available in Indian from some of the high-quality publications such as Wonder house books, Target publications, and locally produced inexpensive booklets as well (Fig. 2). Premium schooling institutions preferred using the expensive books costing around ₹150 equivalent to $2.04 whereas, other average schools were using inexpensive booklets costing around ₹40 which is equivalent to $0.54. Apart from the factors like Page Quality, Printing quality, and size of the books, interestingly the content in both of the books is very similar. Content-wise both of the books follow the same teaching process of associating a letter to any random object whose name is starting from that letter.

5.3 Reviewing Contemporary Learning Mediums

Apart from the traditional method of teaching, video alternatives are also available which are based on, Personifying a letter, Presenting a letter along with a funny voice, Attracting children by motion typography, or just presenting a colorful letter on the screen. Premium schools and parents with access to digital devices and internet connection would be able to show these kinds of videos to the children.

5.4 Comparing the Traditional and Contemporary Mediums

Upon comparing both of the mediums, there's a big gap in terms of ergonomic user experience between both of these approaches, the traditional approach is purely tactile whereas the contemporary one is not. Contemporary learning mediums cannot solve the problem entirely because of the following reasons:

- Learning by watching a video is a particularly non-interactive medium of studying where the critical thinking abilities of children are not exercised.
- Video learning might make children very excited but then, the children will find it difficult to hold such diverse and complex visual and audible information.
- At such a toddler age intensive exposure to the most commonly streaming platforms like YouTube will also expose the children to a lot of distracting content.
- Books can be carried and played around by the children anytime anywhere whereas, it is not always possible to hand them over a smartphone. Also reading books improves the attention spans amongst all of the age groups.

5.5 Hypothesis Formulation

A research has previously been done were, the children of Indian vernacular medium schools were made to learn the English language by using semantic typography, and their first native tribal language [3]. Existing research showed positive cognitive and pedagogical responses from the children, and they were able to learn English much more fluently than before. Taking existing research as a foundation, this research has the potential to be taken forward within the context of ergonomic feasibility. Hence a hypothesis has been proposed which states, that English alphabet teaching using semantic typography will stimulate the constructive cognitive, pedagogical and interactive response in primary grade children.

5.6 Designing Solutions

5.6.1 Initial Survey

Post collecting and evaluating all of the information, the sematic expressions have been designed. In the Initial survey, children were presented with a small set of total eight semantic expressions in the form of a Minimum Viable Product (MVP) to gather their views from an aesthetic and functional standpoint. Some intriguing observations which have been collected from the first survey stage are:

- An inclination towards smooth visual elements.
- Easy to remember and recall visual language.
- Bold and clear typography.

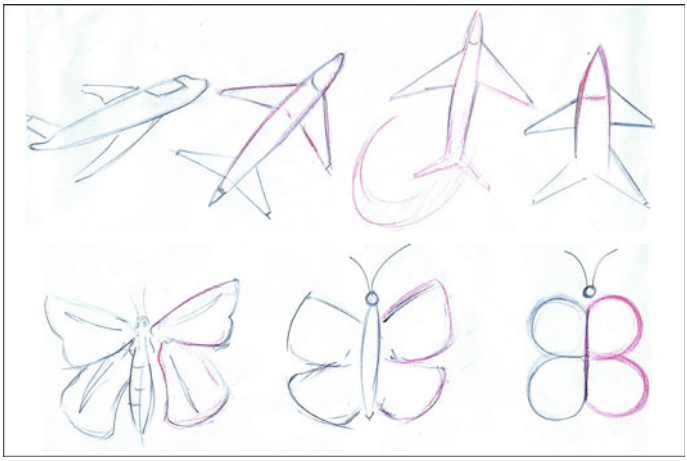

Fig. 3 Drawing explorations from different angles for exploring semantic expressions

- Usage of few colours for clear separation of the letterforms within the semantic expressions.
- Easy to follow and simple steps for drawing semantic expressions.

5.6.2 A to Z English Words Collection

For the next design phase, the target was to design semantic expressions for all 26 English letters. A directory of multiple words starting from every letter in the English alphabet set was made. Upon sorting the suitable words the visuals of different objects were either photographed or collected from the internet.

5.6.3 Sorting and Sketching Semantic Expressions

Collected pictures of the objects from various angles, were broken down into simple shapes for understanding the proportions and legibility. The sorting of the suitable words and then sketching them to visualize the section to fit a letter has been done in this stage as well. (Figs. 3, 4 and 5).

5.6.4 Digital Illustration Process

By using the sketches as a reference, the semantic expressions have been made in a digital drawing software called Adobe Illustrator. The expressions have been designed in the Scalable Vector Graphics (SVG) format, due to which the designs can be printed in any size or colour without the quality degradation.

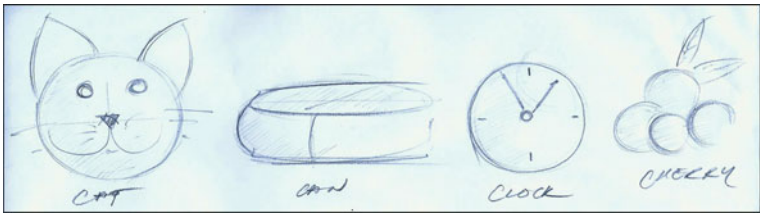

Fig. 4 Selection of the most feasible and easy to draw semantic expression for a letter

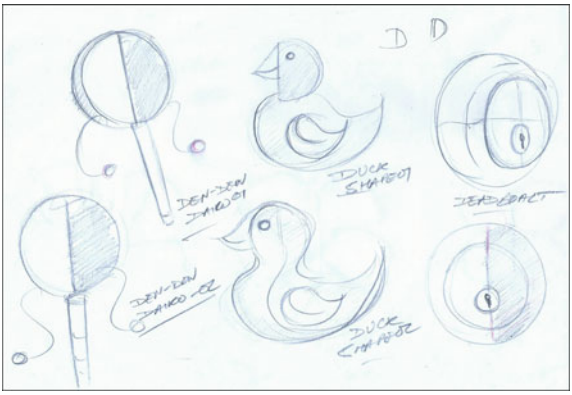

Fig. 5 Converting the complex illustrations into basic shapes for letter matching

5.6.5 Chart Making

After finalizing all of the semantic expressions, a chart has been designed where all of the letters, associated words, semantic expressions and the steps to draw and teach the Semantic expressions in a step-by-step process has been shown (Fig. 6).

5.7 Final Survey

The designed chart consists of all 26 semantic expressions for all of the letters from the English alphabet system. A group 40 primary grade schooling children were invited to a small workshop event for testing this instructional design methodology. To quantify the outcome, their responses were recorded based on four different parameters.

As the teaching volunteers started the session, the children were provided an A4-sized sheet along with the sketch pens and were asked to follow the steps to be able to draw the letter and the sematic expressions by following the instructions.

Based on the observations made from the workshop, overall three stages in which the learning curve can be summed up are shown in Fig. 7.

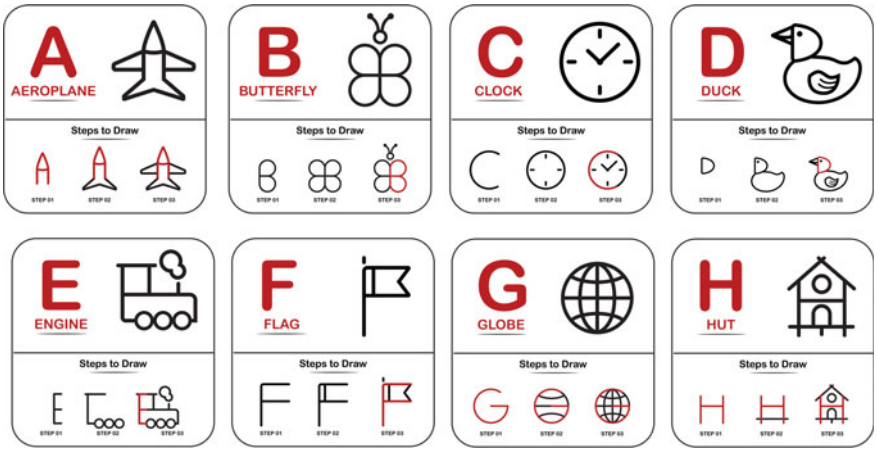

Fig. 6 Chart designed containing Letters, Semantic Expressions and drawing steps for teaching and learning

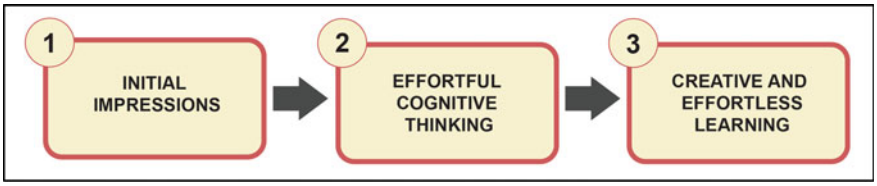

Fig. 7 Three stages of the learning curve

5.8 Three Stages of the Learning Curve

There has been a total of three stages of the learning curve, Initial impressions, Effortful cognitive thinking, and last one being, Creative and Effortless learning (Fig. 7). In the first stage, children were exposed to a very different process of learning, and children were curious and rather got excited when they were informed about a very interesting, interactive, and a new way of learning the English alphabet. In the second stage, children had to put more effort into adapting to the new learning methodology which demanded the 'Understanding' of the concept rather than 'Remembering' them. And in the last and the final stage after learning to be able to draw the first few letters by following the procedure exactly shown in the chart the children got fascinated with the process of learning three aspects at once which are letter, associated word, and drawing of semantic expression.

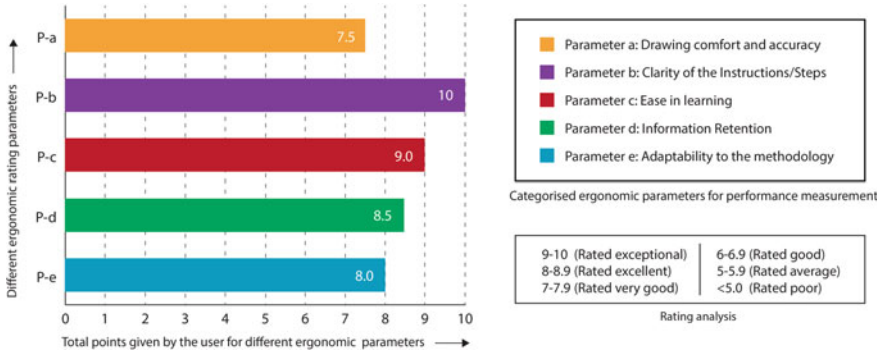

Fig. 8 Consolidated results obtained from the final feedback and review sessions

5.9 Reviews and Feedback

For the final survey there were two different ways, verbal and visual in which the children's response was collected while conducting the experiment. Visually the response was collected based on the drawing sheets which were provided to the children, and an interview was conducted to collect the verbal response. Around 10 questions were formulated for conducting the interview and the children were asked to rate their experience on a scale where 1 point being the least and 10 being the highest performance rating. Sometimes the questions were rephrased once or twice if any of the children were having difficulty in understanding the question. Categorization of the questions has been done in 5 different ergonomic parameters based on the responses provided by the participants. Figure 8 shows a performance bar graph, 4 ergonomic performance measurement parameters, and rating analysis. On the X-axis, the compiled points given by the users are shown and along the Y-axis different ergonomic parameters are shown. On the right of the chart, five chosen ergonomic Parameters and the 1–10 rating analysis are shown.

6 Discussions

Survey results show that ergonomic parameters P-b, P–c, P-d, and P-e are rated as exceptional and excellent. Parameter P-a, drawing comfort and accuracy is rated as very good because learning the English alphabet by drawing objects is a fairly new concept for the children and they were trying their best to draw the figures accurately but some of the children were struggling in doing so. Parameter P-b, Clarity of instructions/steps is rated exceptional because every semantic expression has been broken down into three steps for ease in the learning and teaching process.

Performance measurement by averaging the quantitative data on four ergonomic parameters shows an overall performance rating of 8.6 or 86%, which can be considered as an excellent score to prove the validity of the proposed hypothesis.

After the final survey completion, it was found that the newly proposed methodology was able to successfully facilitate the English learning process for the children of primary grade students. Ergonomically the proposed methodology provided children a holistic way of learning the English language in a fun and exciting way.

7 Conclusion

This case study has been conducted in the form of an exploratory research to enhance the ergonomic pedagogical influence on the children. The interactive nature and user experience of this study contributed to its majority success rate in terms of improving constructive cognitive, pedagogical and interactive response in primary grade children. This study has been built on the foundation of an effective previously conducted case study by us [3] where the challenge was to design an English learning methodology for the children of the Indian vernacular medium school where they were able to use their native tribal language to learn the English language.

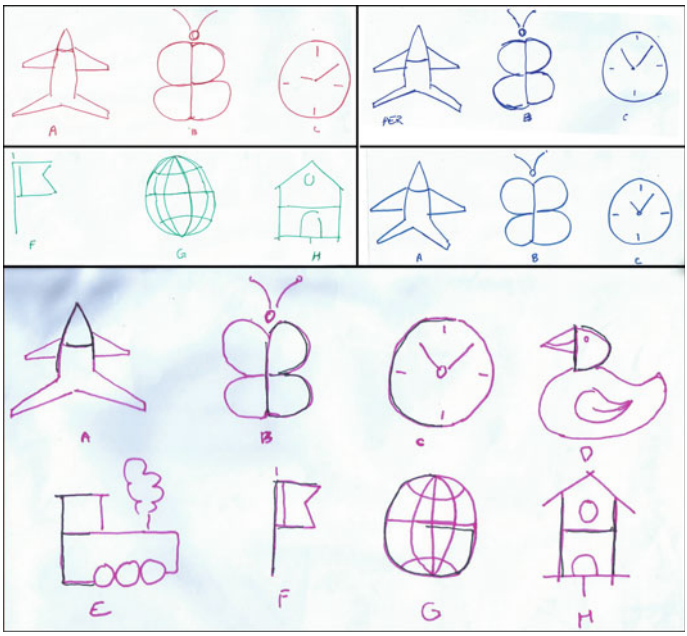

Fig. 9 Sample of the drawings made by five different children by following instructional design

The proposed methodology of teaching the English alphabet by using instructional design and semantic typography showed very convincing results within the Indian context. Most of the children are ready to use it for learning and enhancing their creative expression because of the interactive nature of learning. Others just required slight extra assistance and after that, they were comfortably appreciating and, quickly adapting to the learning process as well (Fig. 9). This, including other instructional design methodologies, can be explored further by the researchers, designers, and teachers to enhance the cognitive learning abilities of the children and make the English learning process more creative, interactive, and ergonomically feasible.

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Sound Design for Cinematic Virtual Reality: A State-of-the-Art Review

Hitesh Kumar Chaurasia and Manoj Majhi

Abstract In the last decade, the rapid development of low-cost 360° cameras, Head Mounted Displays, smartphones, and open-source softwares have created new possibilities of immersive storytelling in virtual reality, popularly known as cinematic virtual reality or virtual reality films. Even in 360° videos, the visual experience remains limited to field of view of head mounted displays. Hence, the spatial audio is considered essential to create 'Presence' and 'Immersion'. The viewer is part of the virtual environment with the freedom to interact, navigate, and choose the viewing direction. This presents challenge of sound recording, designing and playback. The recent development in spatial audio recording, sound synthesis and rendering has addressed some of these challenges. The current study presents the state-of-the-art of sound design in cinematic virtual reality through literature review and textual analysis of the relevant publication in the field since 2015. The objective is to identify further scope of studies. This review could be useful for filmmakers, sound designers, and scholars working in the field of cinematic virtual reality.

Keywords Virtual reality · Immersive storytelling · 360° · Spatial audio · Film Sound design

1 Introduction

Over the years, virtual reality (VR) has slowly and steadily evolved as an independent medium to create simulated experiences in diverse areas such as military training, aviation, health, education, and entertainment. Since 2012 the rapid development of low-cost 360° cameras, Head Mounted Display (HMDs), smartphones and open-source software's have created new possibilities of immersive storytelling popularly known as cinematic virtual reality (CVR) or 360° VR films. While VR can offer

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a full 360° view, at any given instance the visual experience remains limited to the field of view—maximum visual field a VR headset displays. This leads to fear of missing out (FOMO) concern in viewers [1]. To address this, sound's innate nature of omnipresence can be used to localize the source of events beyond the field of view. Hence, spatial audio is considered essential to create 'Presence' and 'Immersion'. However, there are challenges of sound design as, the visual frame that contextualizes the acoustical events no longer exists. The viewer being part of the virtual environment with the freedom to navigate, interact, and choose the viewing direction further adds to the complexity of sound design as well as playback. The current study presents the state-of-the-art of sound design in cinematic virtual reality through literature review textual analysis of the relevant publication in the field since 2015. CVR is in its nascent stage and sound design practices, process, aesthetics, and technology are still evolving. Hence the objective of this study is to present possibilities and challenges of sound design in CVR and to identify the scope of further studies in the field. This could be useful for filmmakers, sound designers, and scholars working in the field of cinematic virtual reality. Section 2 gives the background of CVR followed by Methodology in Sect. 3, literature review in Sect. 4, discussion in Sect. 5, and conclusion in Sect. 6.

2 Background

Through the advancement in motion picture from the silent era, black and white films to talkies and colour picture to 3D Cinema, the objective has been to make the cinematic representation as close to reality as possible. *Sensorama* developed by Morton Heilig in 1956 is regarded as one of the first attempts to create a simulated environment. By 1965, another inventor, Ivan Sutherland, offered "the Ultimate Display," a head-mounted device that he suggested would serve as a "window into a virtual world" [2]. Since then, with the advancement in computer graphics, processing and visual displays VR has evolved as an independent medium. However, there has been debate over 3D and other VR related developments in terms of control over narrative and perception from the very beginning as discussed in *the cinema of the future* by Heilig [3]. In 2012 Palmer Luckey developed a prototype of the Oculus Rift- a portable VR headset offering a 90° field of vision using the computer's processing. In 2014, Facebook acquired the Oculus VR company for $2 billion [4] and subsequently Sony, Google and Samsung also launched VR headsets. Google's low-cost mobile-based do-it-yourself Cardboard brought the VR to the consumer domain. The leading entertainment companies such as Walt Disney and 20th Century Fox also started exploring the possibilities of VR as a medium for storytelling. To create an immersive experience, existing spatial audio format such as Binaural and Ambisonic were further developed for VR. The recent development of Dolby Atmos, wave field synthesis and Head-Related Transfer Function has further created possibilities of immersive sound design and storytelling in CVR.

3 Methodology

A detailed literature search was conducted through multidisciplinary databases for keywords- Sound Design, Cinematic Virtual Reality, Immersive Storytelling, Presence, 360° video, Spatial Audio, Localization, Binaural, Ambisonic and 3D-audio. CVR is relatively a new field hence the initial search was limited from 2015 to present-day publications. Though, some widely referred earlier seminal works were included to define the key theories and concepts in the field. Likewise, some articles from the web were also referred to incorporate the filmmaker's views on contemporary practice and technologies. The publications were shortlisted in a three-step manual process based on relevance, starting from title and keyword review followed by abstract review and finally full paper review. Publication in the domain of pure acoustics, engineering or technology were not included as the scope of the study is the creative application of sound design in CVR.

4 Literature Review

4.1 Immersive Storytelling

In VR, the viewer is part of the virtual world with the freedom to navigate, interact, and choose the viewing direction. This creates a sense of immersion, being 'there' or presence for the viewer. This is the biggest advantage of VR over traditional mediums for immersive storytelling. At the same time, it also presents new challenges to filmmakers as they need to let go of the control over the narrative in terms of framing and editing. Hence, filmmaking tools and techniques developed over the last century needs to be reconsidered and a new filmmaking language needs to be developed for effective storytelling in CVR.

4.1.1 Cinematic Virtual Reality: New Cinematic Language

According to Mateer, cinematic virtual reality provides an immersive VR experience where individual users can immerse themselves in synthetic world experience in 360° Videos [5]. However, this definition uses the term *synthetic world* which refers to computer-generated imagery (CGI) and does not consider live-action 360° films. In a fully virtual experience, the viewer can interact and inform the storytelling. Hence, there is debate, if 360° videos can be considered Cinematic VR. There is an argument that the option to look in any direction also allows the audience to interact with the video and create her own space within the storytelling [4]. This study includes 360° videos also in the discussion.

The traditional notion of the fourth wall no longer exists in CVR. As the viewer is part of the virtual cinematic space with the freedom to choose viewing direction,

interact and navigate. Hence, elements of film language as describe by Bordwell and Thompson for screen-based cinema such as cinematography, mise-en-scene, editing, and sound design [6] needs to be reconsidered and a new film language needs to be developed for CVR. Since the viewer is part of the virtual world, her role and the degree of participation in the storytelling needs to be determined before starting the filmmaking process as this shall influence the overall design of the CVR. Dolan and Parets based on their professional experience in the field proposed a four-quadrant system of storytelling based on four viewer types: Observant Active, Observant Passive, Participant active, and Participant passive [7]. On similar lines, Cho et al. also explored the various approaches of viewer's engagement with the story in CVR such as a first-person (the viewer being addressed by a character in the film) and third person (viewer just observes the action) perspective [8]. The level of control/agency given to the viewer also influences the storytelling in VR and conflicts with the filmmaker's control over the narrative. Ruth Aylett defines it as a "narrative paradox" [9]. Godde et al. conducted an empirical study using exiting 360° videos to understand the possible changes required in CVR from screen-based cinema. Some of the key consideration discussed in the study are to define the the role of the viewer as active participant, or passive observer; guiding the viewer's attention; camera placement; Re-thinking framing and Editing [10]. Although this study does not discuss the sound in detail, it's finding such as placement of story elements, the balance of spatial and temporal story density could inform the sound design as well.

In shooting live action films with a 360° camera, the entire sphere is in frame. Hence there are challenges of location selection, framing, lighting, and sound recording. While Computer Graphics Imagery based films are free from these considerations, creating a realistic environment and process sound to reflects the acoustics of the space remains a concern. Some other studies focused on elements of filmmaking such as editing [11], the interplay between sound design and editing [12] in terms of rhythm, and a framework of screenwriting for an Interactive VR film [13].

4.2 Immersive Sound Design

Humans perceive sound spatially, hence the spatial audio is required to do immersive sound design for CVR as discussed in the following sections.

4.2.1 Perception of Sound

Sound design theories and practices are based on the perception of sound by a human being. Lorenzi explained the way humans localize sound in three dimensions as per psychoacoustics [14]. Further, Kendall demonstrates how sound localization or the sense of direction of a sound is calculated by the brain based on the time difference, phase difference, level difference, and intensity difference between sound signals

arrival at two ears [15]. However, Potisk underlines the limitation of human beings to accurately perceive the distance of a sound through hearing alone and the support of other sensory inputs are required [16]. How the upper human body such as ears, head, torso and shoulders influence the perception of sound in the brain and localize sound is explained by Duda [17]. To compensate for it, in headphone based listening a 3-D audio protocol; Head-Related Transfer Functions (HRTF) captures the transformations of sound wave propagation from the source to the ears [18]. The HRTF is concerned with modelling the physiological responses. These transformations account for the diffractive and reflective influences of the head, pinnae, shoulders and torso, and the combination of two unique HRTFs for the left and right ears satisfactorily addresses the parameters for localization.

4.2.2 Spatial Audio

The human ear can locate source of sound and its direction in three-dimensional space as spatial input. The objective behind the development of a stereo system in the 1930s was to create an impression of a 3D sound environment, surrounding a listener thus simulating auditory reality [19]. For this reason, first Stereo and then multi-channel surround sound system became popular in screen-based cinema even though such format were limited to the horizontal plane. In spatial sound, there are x, y and z-axis for localization. Topping explains that a 3-D audio system can depict a realistic auditory event to an extent that the brain is convinced that a sound originates not from the loudspeakers or headphones, but an arbitrary point in three-dimensional space [20]. In recent times multiple spatial audio formats have been developed. Three widely used spatial audio formats are Binaural, Dolby Atmos and Ambisonic. For the scope of this study, only their main advantages and limitation are summarized in Table 1.

Table 1 Advantage and limitation of three spatial formats

Format	Advantage	Limitation
Binaural (chanel based)	• Normal stereo-file • Compatibility across platforms • Simple and quick spatial audio solution	• Headphone based • Sounds weird on loudspeaker • Rendered mix, no real-time head-tracking
Dolby atmos (object-based)	• Object-based design • Independent of channel/speaker arrangement	• Requires a decoder • Limited distribution and • compatibility
Ambisonic (sound field-based)	• Compatible with other channel-based formats • Scalable with more channels, for 360° videos	• Requires a decoder • The output varies on different platforms

4.2.3 Sound Design for CVR

The sound recording in live-action 360° is challenging as everything is in the frame, it limits the choice of location sound recording equipment and crew. The CGI based workflow does not have these challenges as voices can be dubbed but to process the voices to match the cinematic space as well as build the soundscape from the scratch remains a challenge. McArthur explored the idea of distance in audio for VR and outlined constraints of sound design in terms of hiding the microphone during a 360° shoot to processing in post-production [21].

Candusso [22] study underlines the difference of workflow from linear media to VR, in terms of 3D sound and its applications [22]. However, the lack of consideration of other elements of cinema and key concepts of VR such as presence and Immersion limits the scope of study and merits further exploration. Through case studies, Erkut et al. proposed a framework of sound recording and design for Virtual Environment known as SIVE (Sonic interaction for the virtual environment [23]. To explore immersive production techniques in cinematic sound design, Downes et al. adopted a scene from the 1981 submarine classic film *Das Boot* in a 9.1 loudspeaker configuration. The study suggests that the context is important to utilise this enhanced spatial format [24]. Milesen et al. found that people sense significant more direction in the sound when they get a monoscopic image with ambisonic sound compared to a stereoscopic image with stereo sound, however, they do not feel significantly more direction in the sound when the imagery is monoscopic with stereo sound or when the imagery is stereoscopic with ambisonic [25]. This underlines the complexities of existing formats for both filmmakers as well as viewer.

Even though output from a multichannel speaker system is possible and a framework for the same has been suggested by Sungsoo and Sripathi [26], headphones remain the preferred choice to view VR content with HMDs. Freeman suggests that numbers of channels do not have a significant impact on presence or immersion [27]. While another study suggest that the increased number of speakers and a wider spatial audio distribution diffused the participant's attention [28]. These studies raise some important questions with regards to the relationship of visual attention and a layered spatial soundtrack as well as the time needed to adapt to such complex conditions. The findings of the study are significant to examine the relationship of presence with spatial audio formats. The relationship between sound design and viewer's emotions and reaction has been discussed in several earlier studies [29–31]. One of the relevant studies in this regard is by Kock and Louven [32]. In this study, a Live action and animated film were produced and analysed with different sound treatments. The findings of the study suggest that non-diegetic sound effects for live-action films and diegetic sound in animation film may enhance the impact of the sound effects and lead to greater viewer immersion or suspense. Even though this study is for screen-based cinema the findings are relevant to understand the different approach of sound design required in CGI and live-action based films in CVR. Further, Boltz examined how the viewer's perception of the speed of visual elements gets influenced by the tempo of diegetic sounds [33]. Walden suggests that details in the audio help the

brain process the visuals faster [34], likewise Cheung has shown that using highly expected sounds increases users' sense of presence [35].

4.3 Immersive Experience for Viewer

The experience of CVR differs from traditional screen-based cinema in two aspects first; (a) viewers use head-mounted-display (HMDs) with headphones and experience the content individually; (b) the viewer is present in the virtual world and experience the content as first-person point of view. Hence the idea of presence and immersion needs to be understood in the context of CVR. Lombard and Ditton defined presence as "the perceptual illusion of non-mediation" [36]. This presence, in which the viewer locates herself in the scene, is one of the greatest strengths, but also one of the biggest challenges for storytelling in VR. For effective immersive storytelling, "presence" is the essential prerequisite. The VRs high chance of creating a feeling of presence has been explored, based on the Two-Level Model of spatial presence, introduced by Wirth et al. [37]. According to Slater and Wilbur, while "presence" is the state of being there in the virtual world, "immersion" describes and assess the character of the technology in terms of systems able to deliver an inclusive, extensive, surrounding, and vivid illusion of virtual environment to a participant [38].

A 2015 experimental study analysed the viewer's experience of cinematic virtual reality with head-mounted displays [39]. For the study, a CVR film *The Prism* was produced and viewers watched it on Oculus Rift with headphone. The findings of the study suggest that even though viewers liked the experience of a VR film and could comprehend the story, being able to look around during the film was a distraction for some viewers. Other studies [40, 41] also examined if freedom to look around in cinematic virtual reality enhances the viewing experience or spoils it. This continues to be a topic of debate amongst scholars to date.

The findings of the study by Brinkman et al. suggest that adding sound to the virtual world has a significant effect on people's experience though no difference in experience between stereo and 3D audio was reported [42]. In the same line, another study by Kobayashi et al. suggest that the sympathetic nervous system activated to a greater extent by the spatialized sound [43]. Ding et al. compared a 2D film against a VR film and the findings suggest that CVR has a significant influence on the emotional processing of the audience in comparison to 2D films [44]. Project Orpheus—a practice-based research- examined the idea of presence and immersion in CVR by making user part of the narrative and the use of sound to guide users' attention [45]. This study presents participants two versions of the same video. In version one, the sound matches the visual while in the experimental version the sound announces the upcoming image/visuals beforehand. The idea behind this experiment was to prompt users about a new event such as characters entry through sound. However, the participants of the study found this version of the sound mix as 'distracting' by not finding the corresponding visual of the sound immediately.

4.3.1 Guiding the Attention of Viewer

In 360° CVR often viewers do not know where to look? This results in FOMO (the fear of missing out) complex in viewers [1]. This is a common phenomenon in VR and the storyteller needs to guide the viewer's attention to the key points in the narrative. Rothe et al. summarized the various methods developed in recent years for attention guiding in virtual Reality [46]. Similarly, studies also suggest that depending on the objective, the attention can be space-based (position of an object), feature-based (features of an object) or object-based [47, 48]. The possibility to guide the attention through visual clues is discussed in [49, 50]. These studies also suggest that forced control of user's action may negatively influence presence.

Van der Burg et al. demonstrated through the "Pip and Pop" effect that adding a simple auditory "pip" with a visual colour-change effect "pop" helped in finding the event for viewers [51]. According to Rothe et al. sounds can motivate the user to search for the source of the sound and therefore to change the viewing direction [52]. Binaural audio has a clear advantage to spatial visual processing as it can reduce visual search time [53] However, Mendonca et al. also observed that 3D sound can also have a negative impact on perception [54]. The studies suggest that just like screen-based cinema, in CVR also the sound has to be designed in the context of the narrative along with visuals and the theories cannot be generalized beyond a point.

5 Discussion

The key challenges of sound design in CVR are to define the role of the viewer, to draw the attention of the viewer, and to maintain the sense of presence and immersion. The shooting live-action 360° is challenging as everything is in the frame, it limits the choice of location sound recording equipment and crew. The CGI based workflow does not have these challenges still to re-create voices to match the cinematic space as well as build the soundscape from the scratch remains a challenge. Several studies have shown that sound can be used for guiding attention, but the finding of some studies also suggest it to be distracting as well. The sound design needs careful consideration as any additional layer of sound might be distracting. The same is the case with the use of multi-channel audio output. Though the output through speakers is possible, the preferred mode of audio playback remains headphone, which limits the communal experience of film watching. The advancement in technology such as location microphones, sound field recorders, stand-alone HMDs, HRTF, object-based audio, wave-field synthesis has enhanced the overall sound design for CVR as well as the film viewing experience for the audience. Still the health-related concern of use of HMDs with headphones continues to inform the duration of content as well as its design. This review could be of help to scholars working on the Ergonomics design aspects of HMDs as well. The technologies, processes, and design aesthetics of sound design for CVR is still in flux. The standards are yet to be evolved. In this context, the filmmakers and sound designers need to adapt to the new medium, learn

a few tools and techniques specific to VR. A framework of sound design shall help filmmakers to create immersive experiences.

6 Conclusion

Based on the literature review, it is observed that there is a growing interest amongst scholars in cinematic virtual reality. Still, the studies focused on sound design are rare to find. Simulate reality remains the objective of sound design for filmmakers. Hence it remains the focus of studies as well. While 'being real' might be the primary concern in health, aviation, and military training, in cinematic virtual reality, the role of sound design is to support the narrative and enhance the cinematic experience. Hence there is a need to explore sound design beyond just presence. There is debate over the use of sound and the balance between spatiality, density and guiding the viewers' attention. A detailed study of sound recording, editing, mixing and playback of sound elements i.e., voice, sound effects, ambience, music, and silence is required to develop a comprehensive framework of sound design.

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Traditional Cultivation Practices of Water Chestnut in Northeast India (Assam): A Field Survey

Jitesh Singh Chauhan, Hijam Jiten Singh, and Sougata Karmakar

Abstract Water chestnut is grown as a food crop in most of the states in India. Despite having high medicinal value and economic importance, Indian farmers still follow traditional cultivation practices for water chestnuts. Being informal in nature and not being considered mainstream economic activities, cultivation practices of aquatic food crops like water chestnut, have not received due importance. Thereby, the modernization of the cultivation practices has been ignored. As the cultivation practice is not well documented and not readily available, it could not draw the agricultural researchers' attention for their intervention. Hence, the current research aimed to gather information on the traditional cultivation process of water chestnut along with documenting the challenges in the entire process. To achieve the goal, a detailed survey was conducted from 3 sites that were purposely-selected from the north-eastern districts of Assam, India. It was noticed that the water chestnut cultivation across the sites follows the common five phases: seedling preparation, cleaning of water bodies, transplanting, inter-culture, and harvesting. Cleaning of water bodies and harvesting were found to be more difficult and time-consuming activities. As the farmers need to remain inside the adverse aquatic environment for 5–6 h/day, they suffer from various health-related issues, including body-pain, itching, and swelling in the lower body. The current research findings would facilitate exploring the future research avenues towards increasing productivity, thereby enhancing livelihood and motivating the researchers to come up with intervention strategies for the reduction of the drudgery of the farmers.

Keywords Agriculture · Aquatic crop · Harvesting · Drudgery · Farmers

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1 Introduction

Population explosion is one of the major challenge for the world, it is estimated that by 2050 world population will reach 9.1 billion [1]. Increase in population will rapidly enhance food demand and agriculture production. It is projected that the agriculture produce should be increased by 70% by 2050 to fulfill the food demand [1]. Urbanization has reduced the land for agricultural cultivation. According to United Nations Convention to Combat Desertification, every year 3.3 million of agriculture land is lost due to urbanization [2].

To overcome the challenges many technological interventions are taking place. Precision farming [3], conservation agriculture [4], modern greenhouse, mechanization, and different levels of automation are some examples that have been implemented to increase productivity. Most agro-technologies have been developed for terrestrial agriculture, and aquatic crop cultivation practices are always deprived of receiving the boon of advanced technology [5]. Alternatives should be explored to increase food/crop production to fulfill the rapidly growing crisis in the coming future. According to the Ministry of Agriculture, Govt. of India, an estimate of 11.6 million hectare area of India suffers from the problem of waterlogging [6]. Suitable methods/tools can be developed for the cultivation of aquatic food crops such as water chestnut, lotus, and other aquatic weeds to utilize the waterlogged areas and increase agriculture production.

Water chestnut (*Trapa natans L.*) is aquatic food crop grown in many parts of the world, including India, China, Europe, Africa, and North America [7]. It is extensively cultivated in Uttar Pradesh, Bihar, Madhya Pradesh, and in the north-eastern parts of India [8]. Evidence proved that this plant was used for the nutritional valve during the 4th to 1st millennia BC [9]. Water chestnut cultivation is a source of livelihood for many farmers in India. As well as the fruit has many medicinal valves such as cooling effect, antioxidant, immunomodulatory, nootropic, and anti-diabetic activities [8]. The fruit of water chestnut is a rich source of starch (50%) and having protein (10%) which is similar to the cereals crop [9, 10]. The crop is capable of removing harmful chemicals from the wastewater by taking such chemicals in roots and leaves [11].

The modernization of aquatic agriculture has not received its due attention. While numerous research work is going on in the domain of terrestrial agriculture, very limited studies have been carried out in case of aquatic agriculture. Apart from hardship, low profit, and health hazards, there might be numerous reasons for not giving due importance to aquatic agriculture as the potential food source as well as mainstream economic activities. Lack of modernization or mechanization of aquatic agricultural practices could be attributed to unawareness among the agriculture researchers, engineers, and scientists.

The traditional cultivation practices of water chestnut, an important aquatic food crop, are followed by agriculture workers in an unorganized or informal manner in different parts of India, including north-eastern states. The tacit knowledge of this cultivation practice is not well documented and not readily available to the

scientific community like agricultural scientists, engineers, and research scholars. Thus, very little interventional attempt for improvement of cultivation practices by applying modern know-hows and advanced technologies has happened. With this context, it is felt by the current authors that there is a need for proper documentation with appropriate visuals to describe the traditional cultivation technique of water chestnut. Thus, the present article aims to describe lucidly the step by step traditional cultivation practices of water chestnut along with describing the challenges and future scope for intervention to make the cultivation practice more productive, efficient, and user-friendly.

2 Methodology

Data were collected from three different sites of water chestnut farms located in the north-eastern districts of Assam state, India. The size of the farms that were greater than one bigha was selected for the study from Kamrup rural, Jorhat, and Nagaon districts of Assam. The explorative research method was adopted for the field survey that included unstructured interviews using an open-ended questionnaire, direct observations and documenting (photography and videography) to get an insight of cultivation steps, time required in each step, tools and techniques used, seasons for cultivation, plant's physical properties, as well as challenges (physical challenges, safety concerns, adverse climatic conditions, etc.). The survey process has been summarized in Fig. 1 through a schematic diagram.

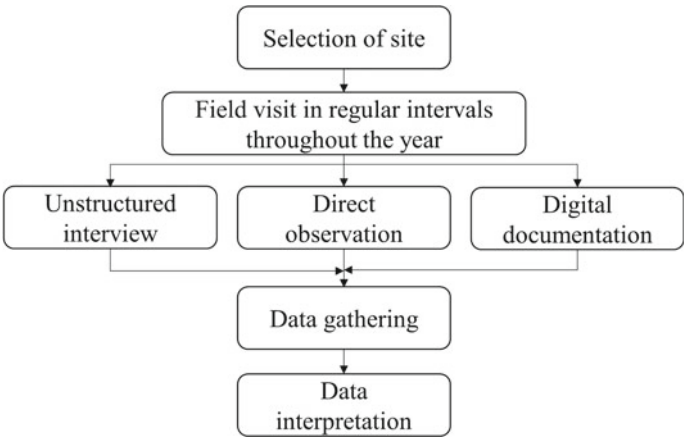


Fig. 1 Schematic diagram of the methodology

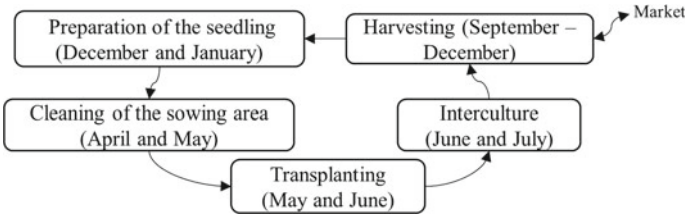


Fig. 2 Cultivation step of water chestnut

2.1 Farmers Details

Farmers having experience of more than three years were interviewed. Consent of the farmers was taken before the field study. Ten (10) farmers from each site were selected for interview. Out of the total 30 volunteers/respondents, only 20% were female. The farmers were economically poor (monthly income approx. 8000 rupees per month, illiterate to semi-literate (maximum school education), and of varying age groups (age: 16–45 years).

3 Findings from Field Survey

3.1 Various Steps/Phases of Water Chestnut Cultivation

Water chestnut cultivation process can be described in 5 distinct steps/phases starting from preparation of seedling to harvesting. Steps involved in the cultivation process are described in Fig. 2.

Preparation of seedling—Fully matured fruits of water-chestnut collected from last harvest in the month of December are sown in an already cleaned water body. The sowing process is completely manual and the farmers insert the seed (matured chestnut) in the soft humus clay below the water with their bare-hands as the depth of the water generally remains low during the month of December–January. The seed germinates and turn into seedling within 3 months (Fig. 3). These plant have tendency to spread so the whole waterbody will be covered with the plants gradually.

Cleaning of the waterbodies—It is done in the month of April and May. The water bodies are needed to be cleaned before transplanting of the seedlings as the water-bodies remain covered with different types of water-weeds that float on the surface. The farmers/workers generally work for about 6 h daily to clean the water bodies. This cleaning of weeds involves removal of floating weeds as well as uprooting of the weeds located at the bottom of the water. Before entering into the water bodies, the farmers tie the bottom portion of the trouser/pant with a rope to avoid entry of any insect inside the trouser (Fig. 4). Moreover, the farmers spread mastered oil

Fig. 3 **a** Seedling of water chestnut. **b** Segregation of seedling by the farmers

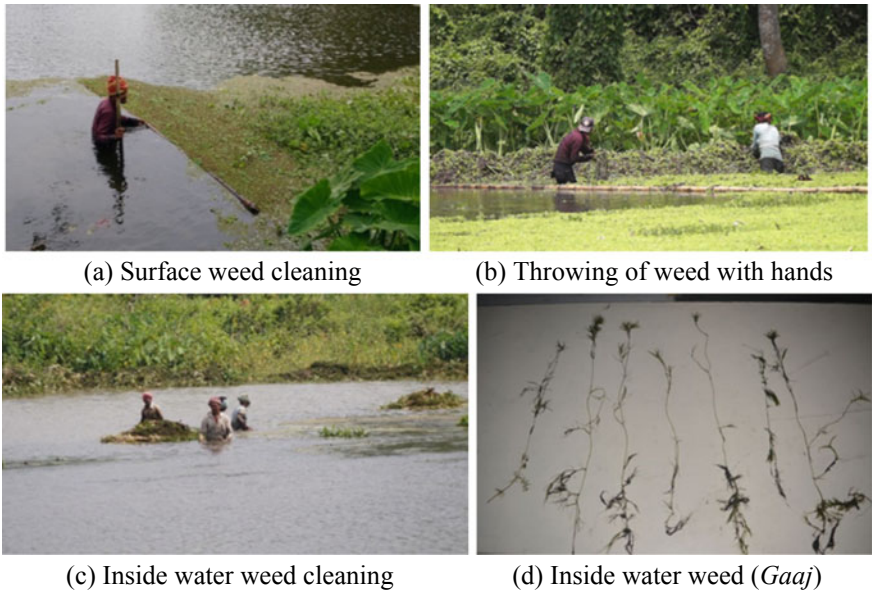
Fig. 4 Farmers tie the bottom of the pant

throughout on their skin as the thin layer of oil on their skin act as water repellent. Farmers reported that the cleaning activities are predominantly done by male workers.

For surface weed cleaning, the farmers use bamboo to push the weeds towards the bank of the waterbody and pile these up as shown in Fig. 5. Then, they pick the weeds with help of hands and throw outside the water body. There is no any specific tool for this kind of cleaning activities, except the sickle for cutting the small trees. Farmers mentioned that about 15 man-days are required to clean the one bigha of waterbody. Farmers reported that they suffer from pain/body-ache in shoulder, hand and leg after performing such activities.

Removal of the underwater weeds is a much difficult and time taking task than the cleaning of the weeds floating on the water surface. For removal of the underwater weeds, farmers push the weed with one leg and then collect these with the bare hands. Farmers reported that there is also no tool or work accessory for this particular activity.

Transplanting—Seedling from the waterbody is taken out for transplanting. Water-chestnut seedlings have long stem portion. Farmer goes inside the waterbody and brings the seedlings by pulling toward the bank/dyke with the help of hand. Individual seedling is cut with an approximate length of 5 ft to make them of equal size for transplantation. Extra portion of the stems are discarded. Then, the seedlings



(a) Surface weed cleaning (b) Throwing of weed with hands

(c) Inside water weed cleaning (d) Inside water weed (*Gaaj*)

Fig. 5 Cleaning of water bodies

are washed to remove any insect or any other unwanted material attached with the seedlings. After washing the whole bunch of seedlings are kept within the fishing-net to carry and taken to the bigger waterbodies for transplantation (Fig. 6a). Here it is worthy to mention that like previous phases, this phase is also completely manual.

While transplanting farmers use their big toe and index toe of the right foot to hold the seedling and push inside the mud in the water bodies for growing them as plants. It is not very time-consuming task it requires only one day to plant 3 bigha land by 3 farmers. Seedlings are generally planted at a distance of 1–1.5 m from each other (both for rows and columns) (Fig. 6b).

Interculture—After transplantation of seedlings, removal of weeds from the waterbodies are carried out in regular intervals. It is done so that weeds do not affect the growth of the water chestnut plant. This cleaning process which is called interculture. Cleaning is carried out till the whole pond is covered with the water-chestnut plant and block the sunlight to enter on the bottom of the waterbodies.

Harvesting—While entering inside the waterbody for harvesting, the workers use to wear shirt and pant to cover maximum body portion and they use to tie the bottom of their pant/trouser by a small rope, so that any water insect like leach does not enter inside the cloths.

During the harvesting activities, farmers carry floating utensil/vessel (shown in Fig. 7a, c) which is used to keep/store the harvested fruits and a net (Fig. 7d) for transferring the fruits from the filled vessels. The harvesting is done 5 to 6 times during the month of September to December.

(a) Taking seedlings to the field (b) Manual transplanting of the plants

(c) View of field after transplanting (d) View of field at time of harvesting

Fig. 6 Transplanting

(a) Entering of farmer in field (b) Harvesting in the field

(c) Utensil to keep fruit (d) Plastic net to transfer fruit from utensil

Fig. 7 Harvesting

Fig. 8 Locally made floating structure to facilitate harvesting in high water-level

The farmer has to pick and turn each plant to check availability of fruits. If the fruit is mature enough to harvest, farmers pluck the fruit and keep in the floating vessel and gradually move for the next plant.

Harvesting in high water level—When the water level is above the chest height, farmers use a boat or a locally made floating structure with light-weight materials (wood, bamboo etc.) to sit upon it. These harvesting aids (floating structures) are not standardized and generally made up of 'Jugad' technique based on locally available resources (Fig. 8).

The task of harvesting of the crop can be divided into following seven sub-tasks. (a) Path—Farmer has to make their path to move forward through the waterbody which is densely covered and entangled with the mesh of the stems of branches of water chestnut plants. They do it by moving the individual plants both on left and right sides to make some movement path forward. (b) Reach—Farmer has to reach near each plant. (c) Pick—Farmer has to pick/hold the leafy portion (by left hand, generally) of each plant and lift it manually above the water surface, one at a time. (d) Search—Farmer has to visually inspect to search the mature fruit by rotating the plant by twisting wrist. (e) Plucking—With the help of thumb and finger of the right hand farmers pluck the fruit. (f) Keeping—After plucking, they keep it in the floated vessel. (g) Transfer—when the vessel gets filled, they transfer the fruits in the net and continue with the empty vessel to fill again.

4 Discussion

It is important for the researchers to have knowledge of plant physical properties for intervention in the cultivation process of water chestnut. The physical properties of

Fig. 9 Water chestnut plant with air sack and fruit

water chestnut plant are very different from the plant found in terrestrial land. This plant grows in stagnant water like lake or pond or marshy land. The roots of the plant are on the bottom of the pond inside the soil. The width of the crown or top portion of the plant is 40–50 cm when fully matured. The crown portion always remains on the surface of the water because of air sacks are attached with the leaves as shown in Fig. 9. The fruit of the plant grows near the stem and just below the leaf of the plant.

It was found that water chestnut plant has long stem portion and because of the long stem and a floating crown (top of the plant) these plant can sustain in increased water level of the water bodies. Due to this unique property of the water chestnut crop, it can be grown in the high flood-prone areas.

Various occupational health related challenges are faced by the water chestnut cultivators. Farmers reported that they have to stay inside the water for long duration, which causes many skin and health problems. Farmer reported that they do not use any protective equipment, 65% of farmer were unaware of such protective equipment while others stated the high cost of these equipment. Due to long stay in water without protective gears 40% of farmers reported swelling of limbs, skin infections, and itching in different body parts. Due to such infections farmer stated that they were not able to continue their work that leads to economic loss and increase medical expenses. Similar problems were reported in the cultivation of makhna, where farmer has to go deep inside the water to collect the makhna seeds [12].

Water bodies are home of many bacteria and other living organism that are not safe for human body. Cyanobacteria, also known as blue-green algae, are commonly found in freshwater lakes and reservoirs throughout the world can affect the skin [13]. Hot tub rash (pseudomonas Dermatitis) caused in humans due to contact of contaminated water for a long period of time [14].

Due to long duration of awkward posture, 68% of farmers reported pain in the lumbar region. Cultivation process of water chestnut requires high work demand and it was observed that farmer has to adopt awkward body posture to fulfil the work demand. Frequent bending was observed in every stages of cultivation process. In seedling preparation farmers need to place mature fruits inside the soil and they need to bend upper body frequently. While in case of cleaning the surface weed, as depth changes gradually from corner to center in most of the water bodies. So, according to the depth level farmers need to opt awkward posture to meet the work

condition. Similar postures were reported in manual harvesting of mussles (aquatic plants) using a boat leads to discomfort in body parts [15].

Nearly, 38% farmers reported pain in knee and lumbar region while harvesting water chestnut on boat because they have to opt crouched posture for long duration. As Lumbar Degenerative Kyphosis (LDK) is a subgroup of the flat-back syndrome and is most commonly caused by unique life styles, such as a prolonged crouched posture during agricultural work [16].

In case of cleaning, 90% of farmers reported that the force required to push water weed with bamboo was very high. The reason of such response could be the water resistance to human movement as it is much difficult to walk in an environment that has water than in an environment that has air. Further, they need to push the weed with bamboo. Hence, farmers need to overcome two forces such as resistance from water and pushing of bamboo with weed, the work is very exhaustive and drain energy very fast.

Around 78% of the farmer also reported discomfort in walking in mercy land. As the field is covered with mercy land, and it is very difficult to keep balance while walking. Foot get sink in mercy surface and get stuck, many times it requires high force to pull the leg and move forward in these water bodies.

In case of harvesting, 32% of farmer reported numbness and pain in the hand. As farmer has to pick each plant from the top (crown), as these plant float on the surface of water. They use one hand to hold the plant, and with help of other hand (with finger and thumb) they plug the fruit. Frequent supination and pronation of forearm was observed for the hand holding the plant to find the mature fruit to harvest. This is done to see the fruit as the water chestnut fruit is found below the crown portion. This activity was very frequent as repeated with every plant.

Around 12% of farmer reported the instances of insect bite and 10% of farmer reported cut in leg due sharp object in the past. The water bodies usually have muddy water and farmer cannot see the bottom surface that can have any sharp object as well as harmful insect. The pond environment is unhygienic due to mud, thorns/prickles [15]. Water bodies can have harmful insects and reptiles like snake and leech (Jonk) inside the muddy soils [17].

Following the field survey various insights of the individual phases of cultivations were gathered. Farmers reported the differences among different phases of cultivation in terms of working capability of individual farmer, level of physical exertion involved, available tools/work accessories and challenges faced by the farmers (as shown in Table 1).

Even though water chestnut plant has high medicinal value and source of income for the farmers, these crops are on way to extinction. The reasons of unpopularity of water chestnut cultivation includes difficult cultivation methods, and unhealthy/unfavorable farming environment, lack of market demand, unavailability of tools/work-accessories to facilitate cultivation etc.

Table 1 Comparison of working capacity, physical demands, tools used and challenges faced in different phases of the cultivation process

Cultivation practices	Area (Bigha/person/day)	Physical exertion	Tool /accessories used	Challenges	Standard tool available	Remark
Seedling preparation		Less	No	Adoption of awkward posture	No	
Cleaning	0.06	High	Bamboo, sickle	Immersed in water for long duration, itching unsafe situation (cut, insect bite, etc.), pain in shoulder, hand and leg,	Costly machines	Needs intervention in terms of hand-tools and personal protective measures
Sowing	1	Less	No		No	
Interculture		Medium		Adoption of awkward posture, immersed in water		
Harvesting	0.10	High	Boat, locally made floating structure	Repetitive hand movement, awkward posture, water contact for long duration and fear of insect bite	No	Needs intervention in terms of hand-tools, personal protective measures, appropriate floating devices etc

5 Conclusion

There is tremendous potential of water chestnut cultivation as a significant contribution for livelihood. In the whole process of cultivation, cleaning and harvesting are the most difficult and time-consuming tasks. Aquatic farmers do not have any standard tools or equipment to perform various activities associated with water chestnut cultivation. Majority of the tasks are performed by bare hands and legs. From the study.

It was found that there is need for intervention in all stages of water chestnut cultivation, particularly in cleaning and harvesting process. Manual or semi-mechanical tools/implements could be helpful for the farmers in the various cultivation process. As robotic or large machinery would not be feasible considering the aquatic farm area and cost of the implements. User-centered design interventions with the feasibility of local manufacturability/maintenance along with human factors should be considered for the intervention in different stages of cultivation of the aquatic crop.

In this article, physical properties, growing environment and steps involved in the cultivation of the water chestnut has been discussed, to get insight of the problem faced by the growers. Insights of the current research would be helpful in the development of tools or techniques to address various challenges faced by the farmers and reduce the drudgery of the cultivators. Scientific community should come forward to carry out research and development activities in the domain of aquatic agriculture most specifically water chestnut for improvement of cultivation practices. These initiative would to address the drudgery of the farmers and ensure enhancement of the overall productivity, and safety.

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Development of an Effective Scale for Measuring Empathy of Indian Nurses

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Abstract Empathy is an emotion that allows a person to enter another's shoes and understand where they come from. It is also an important emotion that empowers healthcare providers to care for patients and each other and is essential to engage patients as partners in care. It is an emotion much needed in nurses as they are in regular touch with patients and their families. However not much study has been done on the empathetic behavior of Indian Nurses. The Jefferson Scale of Empathy (JSE) is the best-known tool globally for measuring empathy in of healthcare professionals. However, there are no existing tools that capture the Indian context for empathy– these factors include the bearing that the socio-economic strata, family and educational background and shortage of resources in the Indian Nursing scenario and their influence on the motivation and empathetic behavior of nurses. This paper addresses a pilot study that was conducted on 18 Indian nurses to arrive at a scale to measure empathy in the Indian Nursing scenario. Various keywords related to empathy were identified from interviews with experts (Human Factors, Healthcare and Behavioral Design). The new empathy scale covers cognitive, affective, and motivational aspects of empathy, and the responses for each item was consistently rated by Indian nurses (Cronbach's alpha > 0.70). Therefore, the new empathy scale is reliable.

Keywords Affective · Behavioral · Cognitive · Communication skills · Empathy · Indian Nurses

1 Introduction and Background References

The word "empathy" is derived from Greek word "empatheia" meaning "affection or passion with a quality of suffering" [1]. Empathy is a critical ingredient for patient satisfaction and improved patient wellbeing therefore must be a part of the entire

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hospital experience for patients [2–4]. It is an emotion much needed in nurses as they are in regular touch with patients and their families [3, 5–7].

Empathy is distinct from Sympathy which refers to the ability to take part in someone else's [4], feelings, mostly by feeling sorrowful about their misfortune, which is not desirable in a healthcare context. Empathy is a powerful ability for healthcare-professionals because patients feel heard, supported, cared for, and validated when they feel someone is taking steps to understand their pain [3, 6].

Hojat concluded that empathy is primarily a cognitive attribute especially in the healthcare context. It involves the process of understanding of a patient's condition and communication of this understanding with the intention to help reduce suffering [4]. Apart from cognitive, there are also affective, and behavioral expressions of empathy [4]. These are measured using self-reported and behavioral tools to understand the internal mechanisms that lead to empathy. The tools for empathy such as the Jefferson Scale of Empathy [JSE) [7] are also based on self-reporting and do not cover behavioral aspects. A comprehensive scale is needed to evaluate all aspects of empathy and its improvement over time. Measuring and consequently enhancing empathy among nurses through training would result in improvement of patient satisfaction and outcomes [8, 9].

Despite the importance of empathy in patient treatment and well being, there is limited published research and data related to empathy of nurses in India. However a study was conducted on empathy levels of Indian medical students using JSE scale and empathy levels were found to be lower in comparison with medical students globally [1].

India has 3.07 million nurses overall including midwives, nurses, women health visitors and auxilary nurse midwives. 1.7 nurses per 1000 people, which is 43% less than WHO norms (Rajya Sabha, March 2020). Nurses in India face several challenges in terms of lack of time and resources due to this fact. The current tools for measuring empathy in the healthcare context do not take into account the Indian context and Indian challenges in the components considered. Many researchers have modified the JSE as per the context of the study and to get better results for empathy measurement [1, 10–12].

2 Review of Literature

2.1 Tools to Measure Empathy

Cognitive, affective and behavioral facets of empathy co-exist [4, 13]. Empathy is measured by using both self-reporting and observational measures to understand the internal neurological and physiological processes that drive it [13, 14].

The Jefferson Scale of Empathy (JSE) is a globally used tool developed to measure empathy in healthcare professionals in the context of patient care [10, 11, 15]. The

Questionnaire of Cognitive and Affective Empathy (QCAE) [14] addresses inconsistencies in other measurement tools such as the Interpersonal Reactivity Index (IRI). It is a reliable tool to measure the different aspects of empathy (cognitive and affective and their respective parts) based on the social cognitive neuroscience approach with respect to empathy and its related neural processes [10, 16, 17].

2.2 *Factors Affecting Empathy Scores in Healthcare Professionals*

Studies have found that nurses who are women tend to score higher than men on empathy scores [1]. Nurses working in different wards in a hospital in Iran underwent a cross-sectional research using the JSE measurement scale. This proved that while there is similarity in results of nurses from different wards, empathy scores increase with experience. Three factors of "Perspective Taking, Compassionate Care, and Walking in Patient's Shoes" were found to be key factors that drive empathy [17].

Research also proves that there is a reduction in empathy scores in medical students as they progress from first year to final year. The maximum decrease in scores is observed between medical students as they progress from second to their third year as they start with clinical training, this being a time when empathic communication is really needed. However, this decline reflects that changes in empathy are found on some parameters that were important and not in others. In fact, some facets of empathy which are thought to be more critical to good physician–patient communication actually improved during this phase [8, 11].

2.3 *Empathy in the Indian Context*

William Chopik of Michigan State University had conducted a study on the country by country ranking on empathy based on data gathered from 104,365 adults spread across 63 countries. The highest scoring countries are Ecuador and Saudi Arabia, and nations such as the US also score very high compared to east Asian countries [18] The African continent mostly scores low and India is comparatively quite average on the empathy score. However, Chopik pointed out that it was only a snapshot and he noted that cultures are constantly evolving therefore there were possibilities for changes in empathy scores (see Fig. 1).

Upbringing, economic strata, culture, age and gender influence the level of empathy of individuals [19]. Indian parenting styles and the education system have a strong influence on the population. Empathy is a much talked about but ignored characteristic in India.

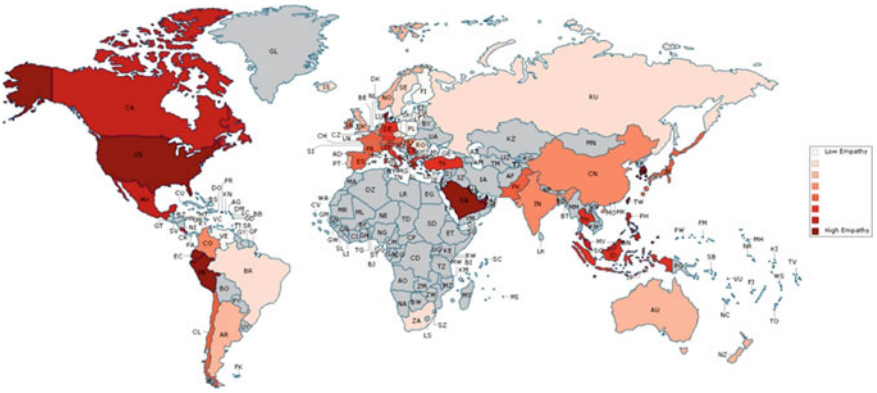

Fig. 1 The world map evolved from William Chopik's study on country ranking on empathy

249 undergraduate medical students of a medical college of Kolkata underwent a cross-sectional study through interviews. The study looked into the sociodemographic profile of the students, their career satisfaction and future career aspirations. The JSE (medical students' version) was adapted for this study. It was concluded that empathy levels of medical students of this study was quite low compared to other studies conducted outside India. Empathy reduced among the students with each semester, which is in line with other research in this regard [1, 20].

2.4 The Indian Nursing Scenario

The nurse-to-patient ratio in India is 3:1777, and as per WHO recommendations, nurses to current population ratio should have been 3:1000, implying a shortfall of 18,09,757 nurses approximately in the country. The attrition rate of nurses in India is 28 to 35% which is much higher than the average in the healthcare sector, which is around 10.1%. A lack of adequate number of institutions providing training in nursing, and migration of nurses to other countries from India are the two most prominent reasons for the shortage of trained nurses in India [21, 22, 25]. Shortage of staff is a strong contributor towards workplace stress for nurses in India which in turn impacts patient care [23, 24, 25].

3 Aim

To conduct a pilot study and design and develop a reliable tool or scale which assesses the cognitive, affective, and motivational aspects of empathy in nurses in India.

4 Methods

Interviews were conducted with five behavioral design experts, healthcare professionals and human factors specialists (having minimum 10 years of experience, Average Age: 37 years) to understand the requirements for empathy scale and to identify a set of keywords related to cognitive, affective, and motivational aspects of empathy. A set of keywords also picked from the existing JSE scale. Then, both sets of keywords have been considered for ratings (on a seven-point Likert scale).

18 Indian nurses from diverse backgrounds in terms of age, gender, marital status, state and type of hospital were administered the questionnaire. (Mage $\pm$ SD = 28.50 $\pm$ 7.84; male = 56%, female = 44%). The nurses were from 19 to 46 years old, belonged to Karnataka, Kerala, Andhra Pradesh, Rajasthan, Tamil Nadu, and Haryana and were associated with Private, Govt, Autonomous hospitals and Universities. Their qualifications included B.Sc, M. Sc and Ph.D.

The scale captured sociodemographic data and included 30 items that captured family support, educational support, and emotional factors for empathy. It measured factors such as individual motivation on the job, understanding of the importance of empathetic behavior in patient treatment. It also evaluated detrimental factors such as stress, lack of training, lack of time and resources, which lead to non-empathetic behavior and conflicts with patients. The items in the pilot empathy scale are listed below in the Table 1. A few questions were adapted from the JSE which have been highlighted in Table 1 as "Existing", whereas new questions have been listed as "New".

Factor analysis (principal component analysis, using 50 iterations and Varimax Rotation Matrix, minimum coefficient value = 0.50) was performed to come up with the new sets of items and the modified empathy scale which was then standardized after reliability check (by calculating Cronbach's alpha).

Table 1 New empathy tool for Indian nurses

S No.	Item	Construct	Type
1	My family gives importance to my feelings in the various contexts of my life	IEENV	New
2	My family has been empathetic towards me since my childhood	IEENV	New
3	My teachers in school understood my feelings	IEENV	New
4	I believe in listening to another person and give importance to their words	COGP	New
5	I believe that entering another person's shoes is an important part of communication during treatment	EMPMO	New
6	My nursing education taught me how to be empathetic with patients	INSRES	New

(continued)

Table 1 (continued)

S No.	Item	Construct	Type
7	I feel motivated to come to my job as a nurse each day	EMPMO	Existing
8	Conflicts at home, work and lack of time stresses me	EMO	New
9	When I am stressed, I may lose my patience with a patient and may not listen completely	NA	New
10	I am stressed because of lack of resources at my work place	INSRES	New
11	I extend immediate help to a patient during therapy without any hesitation	COGP	New
12	I often have conflicts with patients	COGN	New
13	Empathy is a therapeutic skill without which patient care cannot happen	COGP	New
14	I believe in making strong bonds with patients and their family members	NA	New
15	I believe being sympathetic with patients is exhausting for me	COGN	New
16	Patients' body language helps me understand what is going on in their minds	COGP	New
17	I try not to focus on the patient's mood while taking history of a patient	COGN	New
18	I feel I should ask patients about their personal lives to understand them better	COGP	Newly added
19	If a patient is disturbed, I immediately try to understand what is bothering them verbally and through body language	COGP	New
20	I believe practicing empathy can help my patients feel better	COGP	New
21	I find it easy to give bad news to a patient or their family	COGP	
22	I believe I am more empathetic than I was 5 years ago	EMO	New
23	I feel satisfied when I am empathetic with the patient during therapy	EMO	New
24	A nurse's understanding of the emotional status of his/her patients, as well as that of their families is one of the important aspects of the nurse – patient relationship	EMO	Existing
25	I believe that patients feel better when nurses understand their feelings	NA	Existing
26	Attention to patients' emotions is not important in-patient interview	COGN	Existing
27	Nurse's emotional connect with their patients do not have a significant influence in treatment outcomes	EMO	Existing

(continued)

Table 1 (continued)

S No.	Item	Construct	Type
28	Attentiveness of patients' personal experiences does not influence treatment outcomes	COGN	Existing
29	A nurse's sense of humor contributes to a better clinical outcome	NA	Existing
30	Because people are different, it is important to see things from patients' perspective	IEENV	Existing

IEENV: Individual Empathetic Environment, **INSRES**: Individual Stress Related to Resources; **EMPMO**: Empathy related to motivation; **COGN:** Cognitive Negative; **COGP**: Cognitive Positive; **EMO:** Emotional Factors **NA:** Factors not found reliable/relevant

5 Results and Discussions

The nurses responded to the questions on a 7 points Likert Scale. The results were analyzed with 50 iterations and a rating and correlations came out across 8 components.

Item numbers 1 to 3 in Table 2 represent the level of empathy in the individual environment in which the nurse was brought up and currently exists. These came out to be 0.879, 0.573 and 0.843 under factor 1, thus proving that there is a strong correlation between the empathetic environment (upbringing, family, teachers) with the nurses' display of empathetic behavior towards patients. Item 4, 11, 13, 16, 19, 20 are at 0.890, 0.925, 0.733, 0.873, 0.730, 0.923) under Factor 1 represent the cognitive construct and positive mindset of the nurses towards practicing empathy with patients including the importance of listening, observation of patient body language and the understanding of the positive impact of empathy caring for patients. In the Indian context as seen through Item 18, which is at 0.662 under Factor 1 it appears there is a stronger need to understand the family background of patients, which may not be considered important internationally. Nurses are valuing the importance of empathy and many are motivated towards patient care; however, there are several stress factors due to lack of resources and time that have a detrimental effect on the nurse patient interaction in India which comes through in Item 8 at 0.855 under Factor 2. Certain factors such as Item 29, sense of humor during patient treatment which are there in JSR, may not considered a critical factor in the Indian context as it comes under Factor 3 at 0.683 (Table 2).

Table 2 Rotated component matrix

Item	F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8
1	0.879							
2	0.573			0.745				

(continued)

Table 2 (continued)

Item	F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8
3	0.843							
4	0.890							
5				0.872				
6							0.875	
7				0.855				
8		0.855						
9						0.520		
10							. 642	
11	0.925							
12			0.664					
13	*0.733*							
14					0.913			
15			0.787					
16	0.873							
17		0.660	705					
18	0.662							
19	0.730							
20	0.923							
21								
22		0.559			0.557			
23		0.852						
24		0.935						
25		0.871						
26			0.866					
27						0.925		
28			0.874					
29			0.683					
30								0.920

Table 3 Total variance explained

Component	Rotation sums of squared loadings		
	Total	% of Variance	Cumulative (%)
1	7.441	24.804	24.804
2	4.608	15.361	40.165
3	4.192	13.973	54.138
4	2.607	8.689	62.827

(continued)

Table 3 (continued)

Component	Rotation sums of squared loadings		
	Total	% of Variance	Cumulative (%)
5	2.150	7.167	69.994
6	1.986	6.618	76.612
7	1.949	6.496	83.108
8	1.883	6.278	89.385

6 Reliability

The new empathy scale covers cognitive, affective, and motivational aspects of empathy, and the responses for each item was consistently rated by Indian nurses (Cronbach's alpha > 0.70), which is considered reliable overall. The constructs listed in Table 1, related to the empathy in the individual's environment including family and education (IEENV) were found to be at 0.78; Positive cognitive constructs such as the nurse's understanding of the importance of listening, observing body language and the overall importance of empathetic behavior (COGP) came out to be at 0.94, The importance of the emotional aspects of empathetic behavior (EMO) came out to be at 0.72. The negative cognitive aspects such as shortage of resources, stress factors due to stress and home and work (COGN) came out to be 0.88. Pearson Correlation was carried out on the motivation for empathetic behavior (EMPMO) which came out to be > 50 which is considered reliable.

7 Conclusion

Factors such as upbringing, family support and educational background have a strong correlation with empathy displayed in the nurse-patient relationship in the Indian context. Stresses such as shortage of resources and time have a negative effect on nurse empathy. This new empathy scale is effective to measure the empathy of Indian nurses and might further be used by researchers to measure the impact of training on the empathetic responses of Indian nurses towards patients.

Some of the limitations of the tool is that the scale is a self-reported measure, as it is directly reported by the nurses on a Likert scale. Further development of this tool will need include a scale for observers such as doctors and patients to record affective and behavioral traits of nurses.

The next steps for this research will be to test this scale on a larger population, since it has been tested only on a population of 18 nurses. Additionally, the scale would need to be tested further with an Indian and International population of nurses to determine whether the Indian factors identified are accurate and relevant.

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The Impact of Service Quality on Customer Loyalty of Indian E-commerce Industry: The Mediating Role of Customer Satisfaction

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Abstract India has the fastest-growing e-commerce market, which has resulted in widespread acceptance and use. The first impression of a customer is formed by the quality of the shopping website. This paper investigates the service quality of four major e-commerce websites in India's domestic market and explores the links between their service quality and customer satisfaction. The data was collected from 250 customers using a structured questionnaire, and the results were analyzed using PLS-SEM and SPSS 20 statistical measures. Satisfactory service was found to result in higher customer loyalty among online customers. In comparison to amazon, customers who bought from flipkart, myntra and paytm mall were more likely to switch to an alternate website, indicating lower levels of brand loyalty. Empathy had a positive and significant effect on customer's overall satisfaction and in turn strengthened customer loyalty. Customers today differentiate internet-based service companies based on tangibility, responsiveness, and reliability of the companies rather than perceived credibility and security of the services offered, according to the findings. Based on the results it can be concluded that this research offers empirical evidence of the relationship of service quality, customer satisfaction and customer loyalty. Furthermore, the study suggests that to attain maximum customer loyalty, high-quality service should be provided. It was also suggested that existing regulatory agencies be revived to assure the proper implementation of good service quality delivery among India's e-commerce websites.

Keywords E-commerce · Service marketing · Service quality · Virtual enterprises · Consumer preference · Internet marketing

1 Introduction

In India, e-commerce has changed the way people do business. The number of online shoppers as compared to 150 million previous year are expected to increase

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to 190 million in 2021. The increase in internet and smartphone usage has fueled the industry's expansion. The Indian E-commerce market is predicted to rise from US$ 38.5 billion in 2017 to US$ 200 billion by 2026, thanks to the launch of 4G networks and rising consumer wealth. While online retail sales in India are predicted to expand 31% to US$ 32.70 billion in 2018, with Flipkart, Amazon India, and Paytm Mall leading the way [1]. These figures show the importance of service businesses in our society and the necessity to use scientific knowledge to help them succeed.

With the rapid growth of the internet and e-commerce, more people are shopping online these days. Due to its visible impact on a company's financial performance, e-service quality has recently become one of the most important research areas [2]. The service quality (SQL) model of an e-commerce. The retailing industry is seeing similar changes, particularly in consumer products, as e-retailing or e-tailing grows in popularity. Customer satisfaction is a combination of perceived service quality, perceived value, and consumer expectations in general. Customer happiness is likely to influence perceived service quality in a direct and positive way. The benchmark against which performance outcomes are measured is the concept of expectations. This research attempts to construct e-SQL dimensions by adapting the SERVQUAL model to account for the online shopping context and developing a research model to investigate how e-SQL dimensions affect overall service quality customer satisfaction and customer loyalty.

2 Review of Literature

In order to identify a literature gap, a comprehensive review of related empirical literatures is required. This study was able to review and thematically analyse some previous studies, including:

Slack and Singh [3] who investigated the effect of service quality on customer satisfaction and loyalty, as well as the mediating role of customer satisfaction between the dependent and independent variables. The results show that supermarket service quality is viewed as unsatisfactory, but that service quality has a significant impact on customer satisfaction and loyalty, and that customer satisfaction partially mediates the relationship between service quality and customer loyalty, resulting in lower customer loyalty.

Yasa and Wahyuni [4] were able to determine the impact of service quality on customer loyalty and satisfaction as a mediator between service quality and customer loyalty. The findings show that service quality has a little direct impact on customer loyalty. Customer satisfaction has a direct impact on service quality, and customer satisfaction has a direct impact on customer loyalty. Furthermore, the findings reveal an indirect relationship between service quality and client loyalty, mediated by customer satisfaction.

Jiang and Zhang [5] paper examines the service quality of four major domestic airlines in China and the relationship between service quality and customer satisfaction. They discovered that good service did not lead to increased customer

loyalty among business travellers. Customers were more inclined to transfer carriers, demonstrating a lack of devotion to the brand.

Dewi et al. [6] to determine the impact of service quality and customer satisfaction on customer loyalty in the Indonesian laundry service business The findings of this study demonstrated that service quality has a large positive effect on customer satisfaction, and that both service quality and customer satisfaction have significant and positive effects on customer loyalty in Indonesian laundry services.

Sleimi et al. [7] investigated the relationship between e-banking service quality and customer loyalty by mediating customer satisfaction in UAE. The results show that the direct and indirect path coefficient between E-banking service quality and customer loyalty were statistically significant. Moreover, customer satisfaction mediates the relationship between E-banking service quality and customer loyalty.

2.1 Electronic Service Quality

E-SERVQUAL model is applied in various studies [8, 9]; and it is substantial in evaluating customer's experiences in ecommerce business but also in defining the success rate of a firm. E-service quality can also be described as the user's overall assessment of the quality of online facility [10]. This research incorporates the revised E-SERVQUAL model, in which five dimensions are found to be critical in determining Internet SQL in the ecommerce sector: assurance (customer trust and confidence), empathy (individualised attention to customers), reliability (capacity to execute the assured service accurately), and responsiveness (prompt service and readiness to assist customers) (physical facilities).

Relevant studies on e-SQL have analyzed the scale and measured service in numerous settings, including online-based service, online retail [11, 12], and electronic banking. Furthermore, many studies have proposed that SERVQUAL model items must be redeveloped before they can be significantly used in the online shopping context [10]. Additionally, past studies have recommended that perceived SQL influences customer satisfaction [13, 14].

2.2 Customer Satisfaction

Customer satisfaction is described as the way a person feels with regards to delight or disapproval arising from differences made between what he or she expects from using a product and the product's outcome [15]. Also, satisfaction is defined as the feeling a user has after weighing what he or she expected from using a product or service vs what he or she experienced. Customer satisfaction can be used in marketing tactics to assess users' expectations of how organisations deliver goods and services.

2.3 Customer Loyalty

Customer loyalty is a firm commitment to acquire a product or service in the future and to recommend it to others. Customer loyalty is defined as genuine recurring purchases of items or services from the same firm, as well as promoting the company to others, strong devotion to the company by refusing to switch to a competitor.

2.4 Role of Human Factor in Delivering Service Quality

Human factors have been used in a variety of situations. Human factors in product design can make a product more user-friendly [16]. The argument is based on the premise that it varies in services fundamentally in terms of instructiveness. Because of four key differences: intangibility, heterogeneity (or variability), perishability of output (no inventory), and simultaneity of production and consumption. When we talk about the service, the one who is providing service i.e., Website representative is Human and the one who is receiving it is a human i.e., customers. Customers are more interested in the whole process than in the final product [17]. While the degree of intangibility varies by task and industry, the consumer's view of quality is heavily influenced by their experience with the delivery process. As a result, human factors play a critical role in providing high-quality service to clients.

Nevertheless, in online shopping context, few studies have examined the effectiveness of relative service quality dimensions in predicting total service quality, customer satisfaction and customer loyalty.

This study intends to:

(i) to determine the influence of service quality dimensions on customer satisfaction in e-commerce websites.
(ii) to determine the influence of customer satisfaction on customer loyalty in e-commerce websites.
(iii) to determine the mediating effect of customer satisfaction in the relationship between service quality and customer loyalty in e-commerce websites.

3 Conceptual Framework and Hypotheses Development

This study empirically tests the research model that contain three variables in which service quality dimensions is the independent variable, and customer loyalty is the dependent variable and lastly customer satisfaction is the mediating variable.

Assurance. Online shopping context comprises the interaction customers and online stores. Various studies have highlighted the significance of online trust between customers and websites [18, 19]. Consequently, the following hypotheses is proposed.

H1. Assurance in an online website positively influences service quality.

Empathy. The absence of real-time interaction prevent prospective customers from buying through websites [20]. Individual attention, personal messages, and answering client inquiries are all examples of empathy. Earlier research has looked at the impact of e-retailer customer care on consumer perceptions of service quality and satisfaction [21].

H2. Empathy in an online website positively influences service quality.

Responsiveness. The ability of online websites to respond to customers queries quickly. It explains how frequently a website provides services (like- information retrieval, navigation speed and customer's inquiries). Thus, following hypotheses is proposed.

H3. Responsiveness in an online website positively influences service quality.

Reliability. It represents the capability of the web site to deliver orders correctly and timely. To make clients feel safe, online retailers must keep their information secure and guarantee error-free service.

H4. Reliability in an online website positively influences service quality.

Web site design: Web site design quality is vital for online stores. It describes the attraction that user interface presents to customers [2]. Hence, the following hypotheses is proposed.

H5. Website design in an online website positively influences service quality.

Previous researches have suggested that customer perceptions of service quality positively influence customer satisfaction. For instance, [13] noted that overall service quality and customer satisfaction significantly influence customer retention, market share, and profitability. Thus, following hypotheses is proposed.

H6. E-service quality in an online website positively influences customer satisfaction.

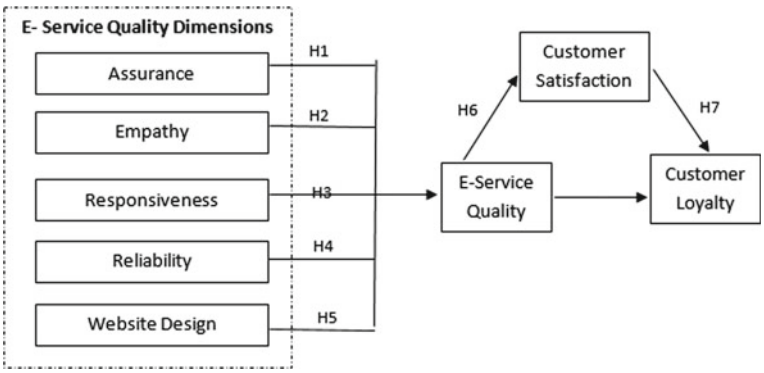

Fig. 1 Conceptual framework. *Source* Researcher's own construction

[22–24] revealed that customer satisfaction plays a mediating role between service quality and customer loyalty and showed a positive and substantial association between customer loyalty and customer satisfaction (Fig. 1).

H7. Customer satisfaction positively influences customer loyalty.

4 Research Methodology

This paper concentrates on the quality of ecommerce websites services and adds to customer satisfaction and customer loyalty. A research questionnaire was created to analyse consumer satisfaction with their online service providers and to quantify service quality. The survey was broken into three sections. It started with questions about respondent's internet usage and opinions of online services. Part two dealt with the respondent's evaluation of the service quality, satisfaction and loyalty constructs in an e-commerce setting which employed 30 Likert-scale items. Items were measured with a modified Likert-scale, (1) strongly disagree and (5) strongly agree. Part three consisted of demographic characteristics such as gender, age, education, and usage related questions.

Experts assessed the questionnaire, and pilot testing was conducted to further validate it. This study's sample comprises of 250 students who have done online purchasing. They were contacted through email using a non-probability sampling method (convenience sampling). The data was reduced to 211 responders after missing and duplicate responses were removed. Confirmatory factor analysis was used to assess the reliability. The KMO was found to be 0.827 with a significance level of 0.000. Three items were found to have low factor loadings; thus they were deleted for further testing, resulting in a total of 27 items. The causal relationships between the constructs were established using structural equation modelling (SEM) and a general linear model of univariate analysis of variance analyses. The former was carried out with Smart PLS software, while the latter was carried out with SPSS 20.

5 Analytical Results

The sample is made up of responses from students at a higher education institution. Table 1 summarises the demographics of the sample. According to the demographic table, 66.8% of respondents were between the ages of 16 and 20, while 33.2% were between the ages of 20 and 24.

Table 1 Profile of respondents (N = 211)

Demographics	Frequency	%
Age		
16–20	141	66.8
20–24	70	33.2
Gender		
Female	142	67.3
Male	69	32.7
Educational level		
Graduate	40	18.9
Undergraduate	171	81.1
For how long you are using web sites for online purchase		
Weekly	36	17
Fortnightly	42	19.9
Monthly	110	52.1
Quarterly	23	10.9
Why do you prefer to shop online		
Very convenience and time saving	114	54
Low price	40	18.9
Products variety	54	25.5
Rare products	3	1.4
Mention the website you use mostly		
Flipkart	65	30.8
Amazon India	113	53.6
Myntra	25	11.8
Paytm mall	4	1.9
Others	4	1.9

5.1 Statistical Results

This study employs the Smart PLS 3.2 version of SEM and bootstrap resampling methods with a sample size of 5,000. This method is utilised to evaluate the estimation as well as the structural model. Discriminant validity and convergent validity are two methods used to assess the model's effectiveness. Tabachnick et al. [25] proposed that things are dependable if the standardised loadings value is more than 0.55, and all of the items are reliable. Convergent validity is also established through the use of procedures given by Fornell and Larcker [26] (Table 2).

Average variance extracted (AVE). To determine discriminant validity, the AVE and HTMT are calculated. Table 3 indicates that for each pair of constructs, the correlation between latent variables is less than the square root of the AVE of each

Table 2 Variables
(Source: Researcher's own compilation)

S No.	Short form	Variables
1	ASS	Assurance
2	EMP	Empathy
3	RESP	Responsiveness
4	REL	Reliability
5	WEB	Website design
6	ESQL	E-service quality
7	SAT	Customer satisfaction
8	CLT	Customer loyalty

Table 3 Fornell and larcker

	ASS	EMP	REL	RESP	SAT	WEB	CLT
Assurance	0.616						
Empathy	0.158	0.726					
Reliability	0.601	0.011	0.747				
Responsibility	0.563	0.097	0.701	0.775			
Satisfaction	0.238	0.011	0.549	0.449	0.910		
Website design	0.434	0.111	0.603	0.630	0.430	0.715	
Customer loyalty	0.604	0.402	0.641	0.753	0.566	0.016	0.843

construct. Cross loadings differences above the accepted standard limits of 0.1 were acceptable. All of the construct values are more than 0.85, according to the HTMT. As a result, because all requirements are met, discriminant validity is achieved. When evaluating a structural model, R^2 is crucial. Figure 2 depicts the R^2 of e-customer satisfaction, which is 27%.

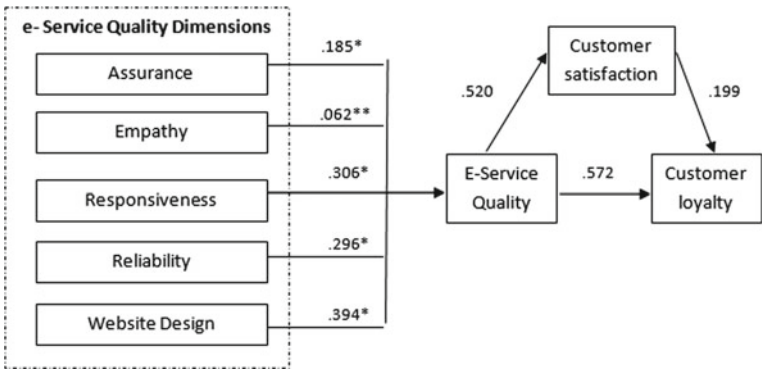

Fig. 2 Pictorial results of path analysis

Table 4 Standardized regression weights (SRW) of the conceptual framework

Hypothesis	Regression link	SRW	T-value	p-value	Remarks
H1	ASS-ESQL	0.185*	6.846	0.000	Supported
H2	EMP-ESQL	0.062**	1.618	0.106	Supported
H3	RESP-ESQL	0.306*	20.681	0.000	Supported
H4	REL-ESQL	0.296*	15.795	0.000	Supported
H5	WEB-ESQL	0.394*	19.044	0.000	Supported
H6	ESQL-SAT	0.520*	7.897	0.000	Supported
H7	SAT-CLT	0.199*	4.524	0.000	Supported

Note(s): * $p < 0.01$, ** $p < 0.10$

5.2 Path Analysis

Table 4 shows the path analysis, which shows the relationship between each link and the hypothesis. The values show how independent variables affect dependent variables, but the hypotheses are determined by the size, significance, and sign of these variables.

Furthermore, p-values are employed to determine the significance of hypotheses, which should be less than 0.1. As a result, Table 4 reveals that because all beta values are positive and significant p-values, all hypotheses should be regarded valid.

6 Discussion

All of the hypotheses were found to be significant; the findings imply that they are not rejected.

H1 (=0.185, $p < 0.10$), is positive and significant, indicating that customers are content with the service when the ecommerce website can meet their demands and deliver services according to their needs.

H2 (=0.062, $p < 0.10$) the hypothesis is not rejected. These findings are in line with previous research [27, 28], which revealed that trust is an important aspect of e-service website performance. The findings suggest that websites that make it easy for customers to access them are user-friendly and convenient. It is therefore noticed that customers prefer user friendliness in all aspects.

H3 (=0.306) is substantial. Shopping websites frequently respond quickly to their customers and tailor their offerings to their preferences. By pleasantly and quickly replying to the user's request, responsiveness requirements are maintained. Customers anticipate prompt delivery, and enhanced security in financial transactions, which may explain these results.

The hypothesis is significant and accepted because H4 (=0.296). Shopping websites should increase their ability to deliver things as promised, provide real-time and accurate information, and improve the security of online transactions to boost customer happiness. These findings imply that by maintaining consistency, shopping websites can increase consumer satisfaction by providing the most accurate information and reliable is the information the greater are the clients satisfied with the service.

H5 ($\beta = 0.394$), is significant for shopping websites. Web design is important dimension of ESQ to attract the customers therefore, the more organized and attractive a website is, the more convenient it will be for the customers to use it and the more satisfied they will be. Shopping websites should pay cautious consideration to this facet. Mostly, site design should be clear, and the user interface should be tidy and visually appealing, allowing customers to use the web site easily.

The connection between Service quality and customer satisfaction denoted by H6 ($\beta = 0.520$, $p < 0.01$) is significant and hence the hypothesis is not rejected. This result is consistent with previous studies. These studies found a positive relationship among overall service quality and customer satisfaction in ecommerce setting.

The last link between customer satisfaction and customer loyalty is significant, thus the hypothesis is not dismissed. We accept the alternative hypothesis since the results demonstrated a significant effect between customer satisfaction and customer loyalty denoted by H7 ($\beta = 0.199$, $p < 0.01$).

Despite the fact that the instrument comprised five dimensions: website design, assurance, reliability, responsiveness, and empathy, the study found similar but somewhat distinct aspects. As a result, the study concluded that in the Indian Ecommerce market, care, commitment, civility, and competence are criteria for service quality. According to consumer responses on a survey, people believe that if the staff treats them with kindness, they will be satisfied. They are willing to stay for an extended period of time. When it comes to underlining the importance of a better customer relationship, there are four primary elements to consider. They are the customer representative personnel's concern, devotion, civility, and competency. Since it is a subject of human factors, it is reasonable to assume that these factors can be characterised as human factors of service quality.

7 Conclusions

Service quality variables are significant factors influencing customer satisfaction levels. However, satisfactory service was found to result in higher customer loyalty among online customers. In comparison to amazon, customers who bought from flipkart, myntra and paytm mall were more likely to switch to an alternate website, indicating lower levels of brand loyalty. Empathy had a positive and significant effect on customer's overall satisfaction and in turn strengthened customer loyalty. Some demographic variables such as gender, income and education are statistically significant for one group of customers that is frequent buyers. It is suggested that

different marketing strategies may be used to target different market segments to improve customer loyalty. We came to the conclusion through data analysis that we needed to improve service quality based on consumer perceptions and experiences. To reach the maximum level of online service quality and customer loyalty in a fiercely competitive climate among organisations with limited resources, firms should concentrate on three factors: empathy, reliability, and website content. The findings of this study can be used to undertake research in the domain of online commerce right now. For example, increasing the level of security, credibility, and responsiveness is essential for attracting and retaining online clients. Second, website design is a crucial tool that should not be overlooked. To make internet transaction processes as simple as possible to use and navigate. Another significant takeaway from this research is the need of assurance and empathy. Customer's demand for personalisation is growing, However, studies reveal that customers are concerned about threats to their personal privacy in online transactions. websites thus ensure that customers should receive appropriate information simultaneously protecting their privacy.

8 Limitations and Future Work

The study has three major flaws that need to be addressed. For starters, the sample chosen was made up of customers of young age, who may or may not be representative of the general population of internet shoppers and might not represent the total population of customers. Second, because this research focused just on shopping websites, it's unclear whether the findings can be applied to other online marketplaces. Because online website's customers perception of service quality is context-dependent, and thus their detailed effects on satisfaction may be tied to specific items and services, future study might use the conceptual framework to investigate various sorts of online retailers. Because of cultural differences in customer satisfaction, generalizability to different nations may be limited. Finally, researcher can investigate the relationship between service quality and consumer satisfaction in online buying situations using various approaches such as focus groups, interviews, and various longitudinal studies. The growth of online purchasing will continue, allowing researchers to study real purchase behavior rather than intentions.

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Science Mapping to Visualize the Factors Influencing Workers' Fall from Height in Construction Projects

C. Vigneshkumar and Urmi Ravindra Salve

Abstract Science mapping is an essential application of visualization technology widely used in safety, psychology, and environmental science. This study used the VOSviewer tool to visualize factors influencing workers' falls in the construction industry. Based on Scopus Index articles published between 2000 and 2019, 343 documents on FFH studies were retrieved, and a total of 96 met the relevance and quality criteria. Using keyword co-occurrence analysis in the VOSviewer tool, the keywords were clustered into different subjects and used to describe the causal factors in the fall from height (FFH) domain. Workers' attitudes, workplace conditions, dangerous tasks, organizational characteristics, agents, and workplace environment were associated with falls. This study's findings will help research into the causes of falls in construction, the development of policy, engineering controls, and intervention design to minimize the risk of falls in the future.

Keywords FFH · Construction · Safety · Science mapping · Factors · VOSviewer

1 Introduction

Compared to other industries, FFH is the leading incident in construction [1]. Still, analysis on why and how FFH incidents happen has not obtained sufficient attention. Human error and accident causation theories should be examined to recognize this scenario [2]. A number of studies were carried out to investigate the reasons or factors which influence the FFH incidents in the construction work in terms of relationships, rates, and proportions [3, 4]. Numerous categories of factors influencing FFH incidents have been studied, such as construction environment, task and activity performed, workers behavior, environmental conditions, surfaces and platforms, and safety standards/regulations [5, 6]. These factors are correlated with each other, such as the experience of workers, and their skills impact individual status, and organization policy affects shift work timing and training courses [7]. To explicate these factors, different forms of research have been performed in various fields, including

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case studies, interviews, surveys, and observations, etc. A review of the literature that captures the variety of studies, aids in in-depth academic research, and also offers an overview of the knowledge field for practitioners can help to fill critical research. A convenient way to gain a comprehensive understanding of a particular domain is a literature review [8]. Hosseini et al. [9] pointed that a review-based study conducted manually leads to bias. To address this issue, many researchers (e.g., [10–12]) adopted science mapping to analyze the documents and field of research in a particular domain. Therefore, this study adopted science mapping to visualize and discuss the factors influencing workers' fall in the construction industry. In summary, the outcomes of a systematic review and the detection of knowledge gaps in established literature will potentially provide researchers and industry professionals with a thorough understanding of the body of knowledge and open the way for future studies to fill a significant research gap.

2 Research Method

This study aimed to visualize the factors influencing FFH focus in published articles in the construction domain. To gather literature SCOPUS database has been widely used in many systematic review studies (e.g., [11, 12]) due to its border scope [9], and therefore in this study SCOPUS database was used to retrieve articles. The following key phrases related to FFH were used to search literature published in Scopus.

TITLE-ABS-KEY ("accidents in construction industry" OR "falls protection" OR "fall(s)/falling from height(s)" OR "fall(s) injuries/accidents /incidents" OR "fall(s)/falling from elevation" OR "fall(s)/falling from scaffolding" OR "fall from roof/scaffolds/ladder/platform" OR "construction."

AND

"construction health and safety").

In a survey conducted between February and March 2021, with the above-mentioned key phrases, 657 articles were included initially. Advanced filter was carried out including document type: articles, timeline: before 2020, source: journals, and languages: English. Journal documents were only chosen in this study due to their reliable knowledge source [13]. Finally, 96 papers were found after limiting the articles to research papers. The selected reviewed paper timeframe was about twenty years published from 2000 to 2019. Figure 1 illustrates the research framework that was used.

The findings of this study are presented based on the FFH studies per year, publications per article source, and the author's co-occurrence network. VOSviewer, a science mapping tool developed by Van Eck and Waltman [14], was used to produce co-occurrence network maps. VOSviewer is more suitable for visualizing extensive networks [15] compared to others such as CiteSpace [16] and Gephi [17]. The working mechanism of VOSviewer can be found in Van Eck and Waltman [15].

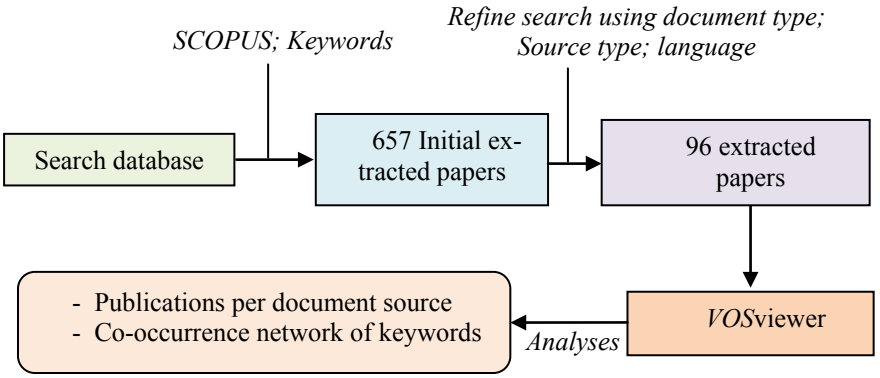

Fig. 1 Framework of research

3 Results

3.1 Publication Per year

The research level and future development in a particular research domain can be understood by plotting the number of literature over time [18]. Figure 2 shows the annual growth of publications trends focusing on FFH studies in the construction field and indicates that there is a variation in number of FFH papers in past decades. The growth of FFH research is due to the huge diligence over repeated incidents in construction workplace [19].

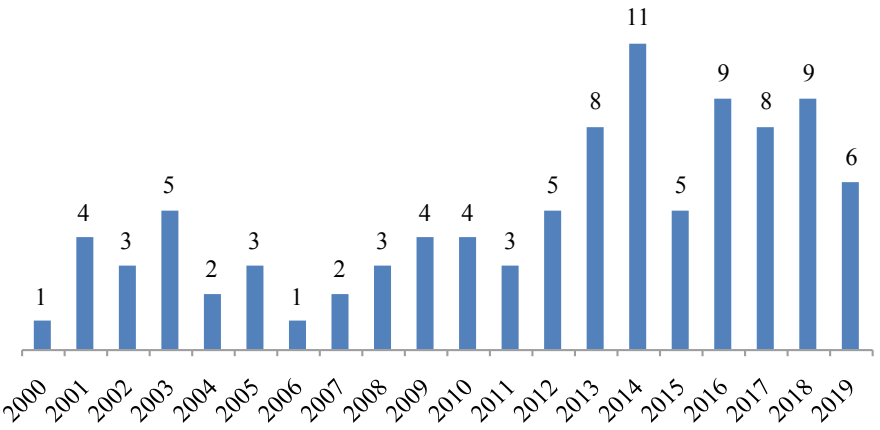

Fig. 2 Number of articles per year from 2000–2019

Table 1 Distribution of selected journals, 2000–2019

Sources	Quantity	Total citations
Journal of Construction Engineering and Management	12	429
Journal of Safety Research	11	664
Automation in Construction	11	567
Safety Science	11	224
American Journal of Industrial Medicine	7	155
Accident Analysis and Prevention	4	129
Journal of Occupational and Environmental Medicine	4	142
Construction Management and Economics	3	126
Ergonomics	3	270
Applied Ergonomics	2	200

3.2 Publications Per Document Source

Within the evaluated time frame, 96 documents were published in 33 different journals. The journals with at least two published papers within the research scope are listed in Table 1. It was found that Journal of Construction Engineering and Management and Journal of Safety Research, with 429 and 664 total citations, are the most influential journals in FFH research. This is followed by Automation in Construction (11 articles, 567 citations), Safety Science (11 articles, 224 citations), American Journal of Industrial Medicine (7 articles, 155 citations), and Accident Analysis and Prevention (4 articles, 142 citations).

3.3 Factors Influencing FFH Base on Authors Co-Occurring Keywords

To describe the concentration domain for particular research, it is essential to clustering the keywords into different themes [20]. By selecting the minimum co-occurrence number of keywords to 2, 123 keywords were initially selected out of 207 keywords in VOSviewer. General keywords such as "construction industry," "fall from height," "health and safety," and so on were removed in further analysis. To the end, 40 keywords were yielded from all 96 extracted articles, which are visualized in Fig. 3. The connection lines in Fig. 2 indicate the closeness among keywords. For example, roof safety is closely related to roofers, which covers research focusing on investigating the factors contributing to roofers' fatal and non-fatal falls in construction [21]. The clustering of keywords is illustrated in Fig. 3. Keywords that belong to the same cluster have a higher co-occurrence rate. The size of font indicates the

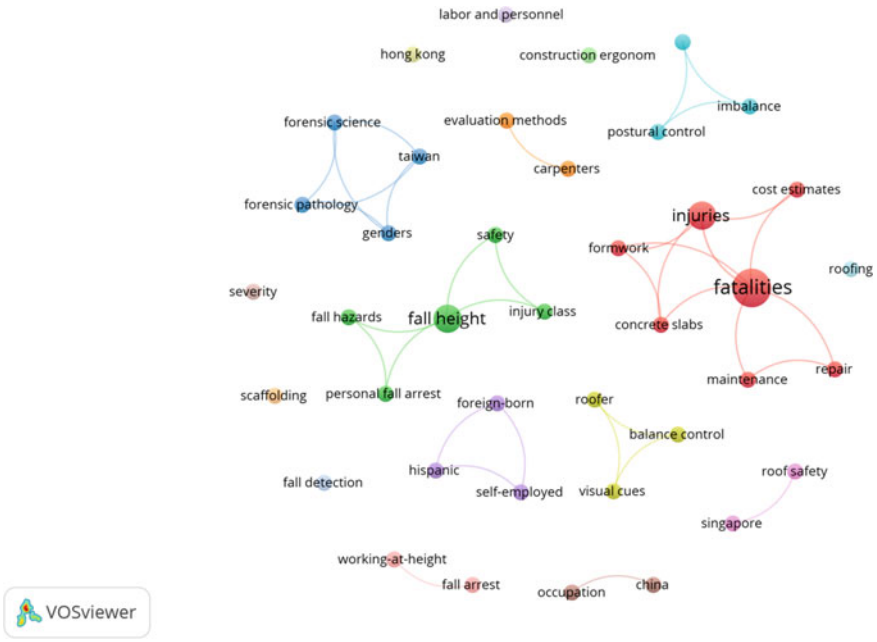

Fig. 3 Visualization of co-occurring author keywords

frequency of keyword that was explored in the selected literature. Figure 3 observations can lead to the following keyword cluster, which describes the mainstream research focusing on risk factors influencing FFH:

Cluster 1—Risky jobs: FFH incidents mainly exist when workers perform dangerous jobs at construction workplaces [22]. Among 96 papers, construction jobs varied depends on the hazardous situation. For example, roofing, painting, carpentering, and concreting are the most dangerous activities in the construction workplace that lead to FFH. Workers who perform roofing tasks are exposed to hazards due to manual material handling, roofing materials, and equipment [23–26]. On the other side, job difficulty diverting workers' attention also leads to FFH while working at height [27].

Cluster 2—Characteristics of workers: Workers' characteristics such as demography (e.g., age, weight, and gender), experience, education, attitude, and health (e.g., fatigue and diseases) are one of the factors that could cause fall [28, 29]. The first characteristic is demography: Gender, marital status, age, weight, height, etc., has a strong association with experience, health, and education of workers. For example, more often, workers are exposed to fatigue which is suffering from overweight, and fatigue is one of the leading causes of FFH [4]. Gauchard et al. [22] stated that aged workers are more involved in FFH incidents than younger ones. Another characteristic is level of knowledge: Workers with lack of experience, lack of skills, and

education [30, 31] not participating in safety training [32, 33] and having poor capabilities, work practices and communication [34] are most likely to experience fall. Human behaviors such as stupidity, carelessness, overconfidence, and misjudgment are among the most critical characteristics that cause FFH, leading to severe injuries or even fatalities [31]. Work depression and lack of sleep are the fourth characteristics. It can be understood that there is a strong relationship between fall hazards and workers' well-being; factors such as work pressure or sleepiness are the leading causes of this relation [35]. Fatigue is also one of the significant reasons for FFH and impacts shift workers [36]. Due to working posture, vulnerability to fatigue could also be increased when working at height for a longer duration [37].

Cluster 3—Condition of workplace: Workers working at height can get impacted in several ways due to the condition of the surface and platform. FFH exists in working surfaces such as improper guardrails, unguarded pathways, and sloped surfaces [38]. Sometimes construction plants are operated during nighttime. The visibility of the environments can get affected due to inadequate lighting during night shifts. Hence, due to lack of lighting, workers may fall [39]. More than 30% of the studies were conducted with agents such as scaffold and ladder. To perform jobs at height in the construction workplace, ladders and scaffolds are used. Fixing and dismantling platforms and ladder is a risky task for construction workers, which may cause FFH and result in deaths [40]. Unfinished construction machines, windows, floors/stairs, scaffolds/ladders, and elevating shafts are significant reasons to fall in the workplace [41].

Cluster 4—Characteristics of companies: Characteristics of organizations are strongly linked with FFH incidents and have numerous components that lead to FFH. Lopez et al. [42] stated that due to high salaries and short occupation periods, workers are increasingly engaged in the small and medium construction business. Kines and Mikkelsen [43] mentioned a strong negative relationship between the size of the company and FFH incidents. Small and medium construction businesses might have improper safety records, such as lack of training courses, defective personal protective equipment (PPE), insufficient fall arrest systems, and so on [44]. On the other hand, contractors also lead to FFH incidents due to a shortage of resources. Contractors are responsible for executing a complicated structure on a day-to-day basis to process the safety rules at the workplace [45]. Fall arrest system and PPE is a vital tool to avoid FFHs at workplaces. But inadequate and improper use of this equipment's and shortage of equipment's will experience in FFH [46–48].

Cluster 5—Environmental conditions: Workers at the construction workplace used to work in an open environment where they face rain, cold, wind, and heat weather. In some cases, the surrounding environment and even climate can result in FFH incidents. Roofers, Steelworkers, and carpenters are exposed to weather conditions [49, 50]. Workers' behavior has to be modified based on the environmental conditions because changing weather is impossible [33].

4 Discussion and Conclusion

Science mapping is a method of recognizing the development process and scientific knowledge structural relationships. The VOSviewer was used to perform multi-angle analyses on FFH research to visualize factors influencing the risk of falls from keyword co-occurrence analysis based on the science mapping. The following are the key findings of the study:

The FFH research has gained attention among the researchers' community; however, the FFH studies were unorganized and scattered in the past two decades. In terms of source journals, the productive journals in FFH are Journal of Construction Engineering and Management, Journal of Safety Research, and Automation in Construction, which serve as essential publication platforms and research findings exchange.

By analyzing the FFH studies and clustering network maps for keyword co-occurrence, the frontier topics in FFH research were grouped based on factors influencing the risk of fall in construction. Current FFH studies focused on examining archival data, which are mostly accident reports or databases. To fit the purpose of FFH studies, these databases have not been designed. Hindsight bias, a psychological concept, is always found prevalent in most of the reports of accidents [51, 52]. This concept is a kind of creeping determinism that means an event was predictable after the occurrence of that event, even though there were fewer chances of the event to occur. Preventive measures should be taken before an accident as prevention is better than cure; it may be very easy to point out the blunders after an accident. After the event of the event, the investigator has no option to retrace the event and take preventive measures. The problem of carrying out research in such a serious issue is that one be suggestive in nature but cannot monitor personally. So, suggesting and implementation are two different tasks; moreover, the accident reports can just give an estimate, they cannot be considered as the primary basis of the problem [51].

Learning from an event is essential; learning concepts and approaches were not embraced in most of the present FFH studies. This restricts the potential of FFH studies to deliver theoretical suggestions for management to develop the learning ability to avoid FFH incidents. Lessons from accident studies are a recent topic in safety research. Multi-disciplinary knowledge ideas should be incorporated to efficiently study FFH events. For instance, examining and evaluating, assessing, and designing interventions are the phases of learning from events [53]. While performing the FFH study, these steps have to be considered. Here, implementing some models for the FFH study can be valuable.

Design for Safety (DfS) is one of the suggestions initiated in a recent FFH study. Nadhim et al. [28] suggested DfS be accepted in the entire project lifecycle. DfS has a huge potential to recognize hazards at the workplace during the whole project lifespan [54]. Advance technology such as virtual reality, building information modeling (BIM), 4D Cad, and wearable monitoring devices should emphasize future FFH studies [28]. Dzeng et al. [35] used a smartphone to spot fall portents at construction workplaces. In recent decades, BIM has been widely used in construction work

to identify hazards [55], for automatic safety inspection [56, 57], to integrate risk factors of safety with BIM for scaffolding [57]. Openings, platforms, surfaces, and scaffolding have been recognized as the risky activities experience by FFH incidents. Further research directions were given by Nadhim et al. [28] to apply BIM technologies for roofing and formworks. Prefabrication is another technology that can reduce the task duration for workers working at height and enhancement of safety performance at the workplace [28].

The limitations of this study are: first, only journal articles were extracted from SCOPUS database; second, articles published in languages other than English were omitted. More research could be conducted in future using other databases or merging to compare findings and get wider view of the research field.

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Assessment of Respiratory Health of Wood and Stone Occupation Workers: A Review

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Abstract Respiratory health of wood and stone occupation workers has become a prime concern due to ceaseless exposure to the accumulation of dust results in respiratory tract infection. Review studies on the assessment of respiratory health of wood and stone occupation workers are up until now lacking, accordingly there is an urge to review such environmental health problems further. The present study emphasizes on the assessment of respiratory symptoms of wood and stone occupation workers along with recognition of associated respiratory disorders. The literature is adopted from Web of Science and Scopus database and by analyzing the abstracts and findings 38 articles have been preferred for this review. The major aim of this review is to present the key factors which are responsible for the assessment and declination of respiratory health of wood and stone occupation workers on a single platform, consequently providing the directions for upcoming research.

Keywords Respiratory health · Respiratory assessment · Respiratory symptoms · Woodworker · Stoneworker

1 Introduction

Vocational exposure to dust is a cause of great concern for the well-being of employees in economically developing nations. Regular and extended exposure to specific annoyance in the workplace may affect the respiratory health of workers and simultaneously it can result in a range of pulmonary diseases that can exhibit sustained impacts, despite exposure discontinues. Particularly, the prime exposure and job-related risk element is dust. The characteristics of the dust exhaled at the workplace are directly associated with the characteristics of the stuff from where it is produced [1]. Particular occupations such as woodwork and stonework, due to the

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characteristics of their site, job, and environmental conditions, are at higher exposure for occupational pulmonary diseases than others. Diverse pulmonary diseases concerned with exposure to respirable synthetic dust [2]. Functioning in dusty workstations are closely allied to a high prevalence of respiratory disorders [3]. It is identified that saw dust raised the probability of growing lower and upper respiratory ailments specifically in woodwork occupation [4]. The growth of respiration difficulties in woodworkers is entirely depends on pre-disposing host elements and environment conditions, substantially the type and severity of dust exposure.

As per the National Institute of Safety and Health (NIOSH), industrial enterprises whereat employees are subjected to silica dust include occupations such as stone crushing, stone grinding, stone and granite carving, mining, asphalt work, gemstone working, and cement manufacturing units [5]. In stonework occupation, continuous exposure to silica dust can affect the respiratory health of workers and it may lead to diverse pulmonary ailments [6]. Occupations concerned with woodwork and stonework, accumulation of fine dusty particles in lungs may results in severe pulmonary diseases among the associated workers. A meta-analysis on job-related exposure of woodworkers reported a significant threat of asthma [3]. So far, no review study is available on the assessment of respiratory health of wood and stone occupation workers. Therefore, the present study emphasizes on the assessment of respiratory health of wood and stone occupation workers along with recognition of associated factors for the degradation of respiratory health.

2 Data Collection and Methodology

2.1 Search String

In this review study, the literature is extracted from Web of Science (WoS) and Scopus database. Applying varieties of the search string [(“respiratory health” OR “respiratory disease” OR “respiratory symptoms” OR “dust exposure” OR “silica exposure” OR “quartz exposure” OR “pulmonary functions” OR “silicosis”) AND (“wood worker*” OR “wood carving” OR “Furniture factory worker*” OR “stone carver*” OR “stone grinder*” OR “stone grinding” OR “pestle worker*” OR “gemstone worker*”)] in the two databases enabled the detection of 83 articles (28 from Web of Science and 55 from Scopus). The scanning of articles is conducted on 15th May, 2021.

2.2 Screening of Articles and Inclusion/exclusion Criteria

The searched articles were further refined by applying variations of inclusion/exclusion criteria. The Web of Science articles were refined by document type

(article, proceeding paper), language (English) and research areas (public environmental occupational health, genetics heredity, physiology, toxicology, immunology, radiology nuclear medicine medical imaging, environmental sciences, infectious diseases, respiratory system, allergy, medicine research experimental, tropical medicine, biodiversity conservation, multidisciplinary sciences). The Scopus articles were refined by document type (article, conference paper), source type (journal), language (English), subject area (medicine; environmental science; biochemistry, genetics and molecular biology; pharmacology, toxicology and pharmaceutics; agricultural and biological sciences; immunology and microbiology; multidisciplinary). The application of inclusion/exclusion criteria resulting in 70 articles. Further, the articles are refined on the basis of duplicity check and reading abstract and title. Finally, after the detailed content analysis, a total of 38 articles were selected for review. Figure 1 shows the flow diagram of articles selection process.

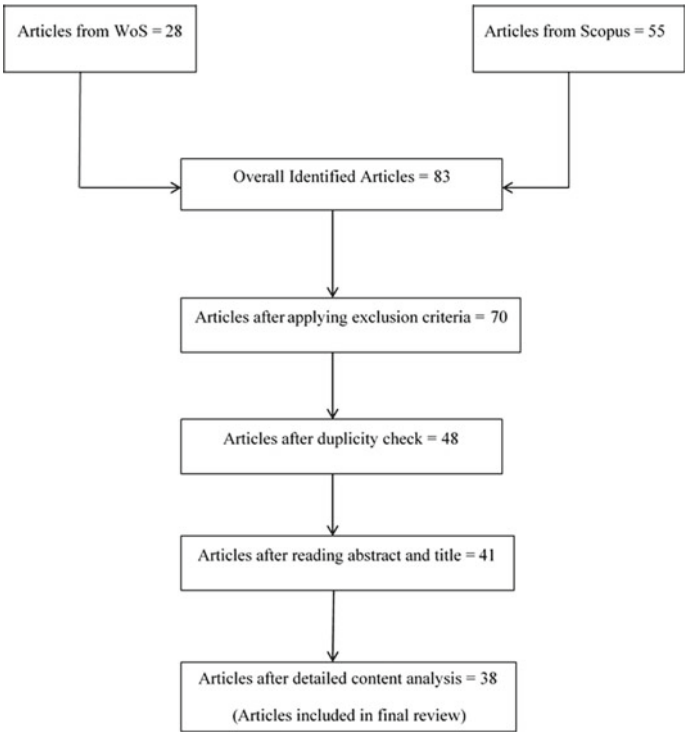

Fig. 1 Flow diagram of articles selection process

3 Explanatory Results and Discussion

Thirty-eight articles were preferred for this review study. Regarding 38 adopted articles, 25 are particularly concern with the wood occupation and rest 13 are related to the stone occupation. So, occupation-wise descriptive results for the multiple performance parameters are presented under this section.

3.1 Research Amplification

The frequency distribution of the publications opted for this study is slightly sporadic. Figure 2 indicates the spread of the articles over the last 33 years, from 1987 to 2020. It appears that such issue has not been extensively addressed as of the time.

The spread of articles concern with wood and stone occupations has been shown in Fig. 3. It can be revealed that almost 44% of the wood occupation articles were reported since 2010 and that indicates the significance and concern of the subject. At the same time, about 23% of the stone occupation articles were published and it reflects the less interest of researchers in the concern topic.

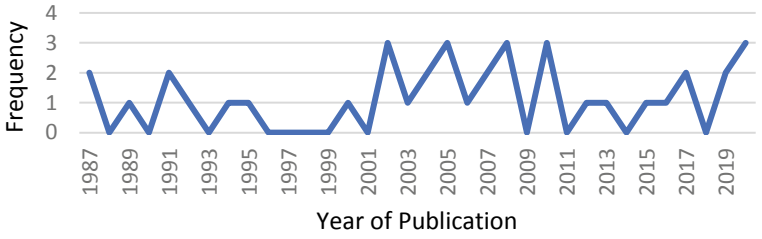

Fig. 2 Cumulative distribution of the articles

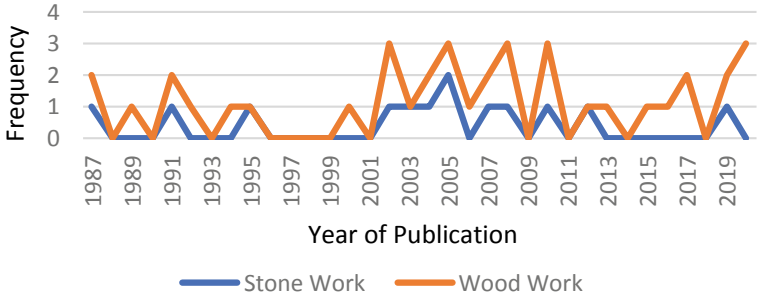

Fig. 3 Distribution of the wood and stone occupation articles

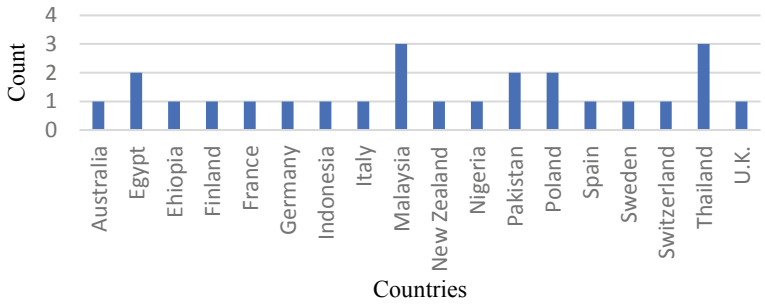

Fig. 4 Country-wise distribution of the wood occupation articles

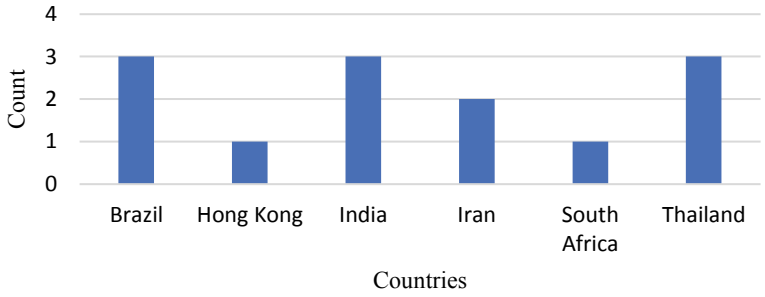

Fig. 5 Country-wise distribution of the stone occupation articles

3.2 Country-Wise Evaluation

From obtained data, participatory nations in the context of number of publications, is analyzed in this part. Figure 4 shows country-wise distribution of the wood occupation articles and it implies that countries such as Malaysia and Thailand have thoroughly participated in concern research topic with the contribution of 24% published articles, followed by Egypt, Pakistan and Poland.

Country-wise distribution of stone occupation articles is shown in Fig. 5 and it is evident that countries such as India, Brazil and Thailand have highest contribution with 69% publications. There are only six nations which have shown interest in this topic.

3.3 Journal-Wise Analysis

This section provides the information's regarding the journals that published various studies concerned with the assessment of respiratory health of wood and stone occupation workers. Table 1 shows journal-wise distribution of wood occupation articles.

Table 1 Journal-wise distribution of wood occupation articles

Journal	Count
Occupational and Environmental Medicine	4
Annals of Occupational Hygiene	2
International Journal of Occupational and Environmental Health	2
Allergy: European Journal of Allergy and Clinical Immunology	1
American Industrial Hygiene Association Journal	1
Annals of Agricultural and Environmental Medicine	1
Archives of Environmental and Occupational Health	1
Archives of Environmental Health	1
British Journal of Industrial Medicine	1
Human and Ecological Risk Assessment	1
Human and Experimental Toxicology	1
International Journal of Environmental Health Research	1
International Journal of Occupational Medicine and Environmental Health	1
Journal of Physiology and Pharmacology	1
Malaysian Journal of Medicine and Health Sciences	1
Nigerian Journal of Physiological Sciences	1
Online Journal of Health and Allied Sciences	1
PLoS ONE	1
Scandinavian Journal of Work Environment & Health	1
The New Zealand medical journal	1

Twenty-five articles have been published under twenty journals. Occupational and Environmental Medicine has the maximum number with a total article of 4, chased by the Annals of Occupational Hygiene with 2 articles and International Journal of Occupational and Environmental Health with 2 articles.

Journal-wise distribution of stone occupation articles is shown in Table 2. There is a total of eleven journals who have published their work related to the assessment of respiratory health of stone occupation workers. American Journal of Industrial Medicine and International Journal of Occupational and Environmental Health are the leading journals who have published almost 30% articles related to the topic.

3.4 Analysis of Assessment Tools and Techniques

Studies concerning assessment of respiratory health of wood occupation workers such as Yusof et al. [4], Carosso et al. [7], Pisaniello et al. [8], have used modified British Medical Research Council (BMRC) questionnaire for the analysis of the

Table 2 Journal-wise distribution of stone occupation articles

Journal	Count
American Journal of Industrial Medicine	2
International Journal of Occupational and Environmental Health	2
Archives of Medical Research	1
Eastern Mediterranean Health Journal	1
Indian Journal of Occupational and Environmental Medicine	1
Inhalation Toxicology	1
American Review of Respiratory Disease	1
Journal of Computer Assisted Tomography	1
Journal of the Medical Association of Thailand	1
Revista Portuguesa De Pneumologia	1
Southeast Asian Journal of Tropical Medicine and Public Health	1

respiratory symptoms of workers while many studies rely on self-structured respiratory symptom questionnaire [2, 9–15]. Sriproed et al. [16] and Thepaksorn et al. [17] have applied modified American Thoracic Society (ATS) respiratory symptom questionnaire while Bohadana et al. [18] have utilized European Coal and Steel Community questionnaire for the assessment of respiratory symptoms. Hosseini et al. [19] have employed modified European Community Respiratory Health Survey (ECRHS) questionnaire. Most of the studies applied spirometry for the determination of lung capacity of wood occupation workers [1, 2, 4, 7, 9, 10, 13–22]. Few studies also employed chest radiographs to investigate the chest conditions of woodworkers [1, 21]. For the further assessment of pulmonary health of woodworkers, researchers also employed few additional techniques such as serological tests [7], formaldehyde assessment [8], blood test [14], methacholine bronchial challenge test [18], nitrogen washout [20], computed tomography scan of the thorax [21], endotoxin sampling [23], liver function test, sputum test [24]. Thus, most of researchers have used spirometry to assess the lung capacity of woodworkers.

Studies of White et al. [25], Yingratanasuk et al. [26], Thongtip et al. [27] have utilized modified ATS questionnaire for assessing the respiratory health of stoneworkers whereas few studies have applied BMRC questionnaire [28, 29]. Authors such as Mohebbi and Zubeyri [30], Bahrami and Mahjub [31] have employed self-structured respiratory symptom questionnaire. Majority of researchers have utilized the combination spirometry and chest radiography for the better analysis of the respiratory health of stoneworkers [25–29, 32–35]. Apart from such techniques, researchers also applied body pletismography [29], X-ray diffraction analysis [36], high-resolution computerized tomography (HRCT) [37] for the deeper investigation of workers health. Hence, the combination of spirometry and chest radiography is

much preferred by the researchers for the assessment of the respiratory health of stoneworkers.

3.5 Analysis of Respiratory Problems

Various studies have reported that most common respiratory symptoms of woodworkers are chest tightness, shortness of breath, cough, phlegm, and wheezing [4, 10, 15, 17, 19]. Continuous and extended exposure to wood dust may cause the prevalence of respiratory disorders such as chronic obstructive lung disease [7], occupational asthma [3, 9, 10, 38, 39], allergic alveolitis [21], bronchial hyper responsiveness [18], nasal cellularity [11, 16], lung cancer [1, 24] and adenocarcinoma of the nasal cavity and paranasal sinuses [12]. Studies of Alexandersson and Hedenstierna [20] and Pisaniello et al. [8] have reported that formaldehyde exposure may results in prevalence of transient lung function impairment. Thus, the studies indicate that usual respiratory ailments among the woodworkers are occupational asthma, nasal cellularity and lung cancer.

Few studies stated that usual pulmonary symptoms of stoneworkers are wheeze, cough, phlegm, breathlessness, chest pain, dyspnea and chronic bronchitis [26, 28, 31, 34, 37]. Regular exposure to silica dust may leads to various respiratory ailments such as pneumoconiosis [28], silicosis [29, 30, 32], silicosis along with tuberculosis [25, 26, 34–36]. Aungkasuvapala et al. [36] have mentioned that the occurrence of silicosis and tuberculosis was allied to duration of work exposure. Hence, majority of researchers have emphasized on prevalence silicosis and tuberculosis among stoneworkers.

4 Conclusion

This study has carried out to present a review of literature on assessment of respiratory health of wood and stone occupation workers. The review has presented crucial information regarding research growth, country-wise and journal-wise analysis, analysis of assessment tools and techniques, and analysis of respiratory problems. The study has also recognized the subsequent gaps in available research that may be addressed as directions for further research.

- Existing studies concerning assessment of respiratory health of wood and stone occupation workers are very less in numbers.
- There is a lack of Indian study, especially in the field of assessment of respiratory health of woodworkers. Hence, it should encourage the researchers to work towards this particular topic.
- So far, there is a requirement of an effective intervention study that can resolve respiratory health issues of wood and stone workers.

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Analysis of Risk Factors (Psychological and Musculoskeletal Disorders) Associated with Smart Phone Usage Among Indian Users

P. Shrisowmya, K. Adalarasu, S. Monisha Gowri, and T. Aravind Krishna

Abstract Smart phones have become an integral part of our life. However, excessive usage of the smartphone can affect postures and lead to pain, musculoskeletal disorders, or change in the behavior of individuals. In this study, we investigate the psychological and musculoskeletal issues related to smartphone usage associated with smartphone users in India. Eighty Indian participants were involved in this study. A questionnaire involving 2 sections (to assess psychology and musculoskeletal issues with smartphone users) was developed and surveyed among the participants. RBG pain score was used for rating pain (where 0 designates no pain and 5 designates severe pain). From statistical analysis, 96% of the respondents feel that smart phones are a necessity and not a luxury. 90% of the respondents are happy/very happy with their smartphones. 85% of the respondents feel that the brand of their smartphones is very important/important/fairly important. 31% of the respondents are addicted to mobile phone usage. Respondents using bigger displays (>5.5 inches) have more pain in their fingers, hand, and shoulders compared to smaller displays (<5.5 inches) respondents. Respondents using tempered glass display have less pain in their fingers, the base of the thumb, and front of hand compared to tempered glass display respondents. These results indicate that smartphones are a necessity and appropriate ergonomics issues need to be considered and addressed to develop a better design of smartphones that ensure the health and wellbeing of users.

Keywords Musculoskeletal disorders (MSD) · Smart phone · Ergonomics · RBG pain score

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1 Introduction

Smartphone's usage has drastically increased over the past few decades especially the past year due to the present COVID-19 scenario, where its usage has increased due to work from home situations. Combining internet use with phone calls to do daily duties on a smartphone, on the other hand, may result in smartphone addiction. The pandemic has also forced the use of the smartphone for many daily activities such as online classes for students, video calls for working professionals, etc.

The prolonged hours of usage have led to many health issues. Smartphone addiction is also one of the growing health concerns which demands research to analyse and suggest the harm effects due to extensive use. Overuse of mobile devices has been linked to development of musculoskeletal disorders (MSD) in hands, forearms, arms, and necks. Touch screen when not used properly is observed to have negative impacts on the health—MSDs and related injuries. Many studies also have reported that extensive smartphone usage can lead to serious health problems such as weakened concentration, headaches, insomnia etc.

The study of usage of digital devices by students can have both positive and negative effects, depending on the manner in which it is used. The study emphasizes on the negative effects of smartphone usage. For example, there are high chances that if not rigorously managed, students who are addicted to their smartphones check notifications regularly. The study concluded that there is a mixed effect (positive and negative) of smartphones on academic performance with challenges, as excessive usage of the smartphone can affect postures and lead to pain, musculoskeletal disorders, or change in the behaviour of individuals [6].

The study of the excessive addiction to smartphones not only leads to behaviour changes but also leads to anxiety, depression, sleep quality, etc. [7]. Therefore, individuals should consider the after effects of digital devices such as smartphone use on physical heath. When users perform repetitive operations, holding mobile phones necessitates a considerable load and force. Users of mobile phones are found to hold them below eye level that necessitates neck flexion [4].

The typing style and posture of students when testing using digital devices and reported that most of the students flexed their neck and wrists; almost 50% of the students typed using both their thumbs while and 33% typed with one thumb [3]. It is likely that the time spent using digital devices such as mobile phones (with small screens and small texting keyboard) is likely to increase because of the increasing dependency on phones and ever-expanding applications. The muscles, tendons, and ligaments of the neck are designed to sustain the weight of the head (10–12 lbs) in a neutral posture above the cervical spine. People who text on their phones often tilt their heads forward and down at angles of 45–60°, exerting 50–60 lbs of force on the neck. which is shown in Fig. 1. The neck by design, cannot withstand this level of pressure over extended time periods.

The study of the muscle activity such as abductor pollicis longus (APL), abductor pollicis brevis (APB), extensor digitorum (ED), and left and right trapezius during working with smartphones using Electromyography (EMG) signal. This study

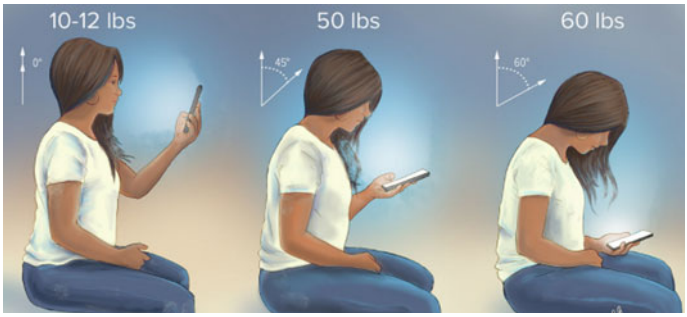

Fig. 1 Position of Head and Neck at different angles during texting [1]

concluded that abduction/adduction finger motions develop at a faster rate than flexion/extension finger motions.. Likewise, exploratory and observational investigations have provided details regarding the potential actual dangers identified with messaging. In a trial among youthful grown-ups, the study reported contrasting pose, typing style, and muscle actions (during message texting using smartphones) between those with and those without musculoskeletal manifestations in the neck and upper extremities [2].

Keypads and typing styles and their association with MSDs also need to be analysed. A study found that there is no link between keypads and typing styles, but that these factors affect the finger muscles rather than the trapezius [5]. There are also a few studies conducted towards analysing ways of reducing risk and improve gadgets for users. The study of MSDs/pain complaints associated with smart phone usage and concluded that information should be collected about prolonged or extended hours spent sitting and engaging in moderate or vigorous physical activities (MVPA) including daily life activities [8].

There are many studies on the usage of smart phones but there is a dearth of studies on MSDs associated with different smart phone specifications such as display size, temper glass etc. and customer psychology behind smart phone selection and usage [12]. This study in an attempt to fill in this gap will analyse the MSDs associated with smart phone specifications and understand the customer psychology behind smart phone selection and usage and users in India. Also, during pandemic times it is important to understand how smart phone usage affects the health of users. Specifically, here we study musculoskeletal disorders due to smart phone usage.

2 Methods and Materials

2.1 Subject Summary

An ergonomics survey with the aid of a self-assessment questionnaire was conducted using google forms from various regions of India and we received 80 responses (45 females and 35 males) with age in the range of 20–40 years (the average age was found to be 30 years). The average height of the users was found to be 162 cm (162.9 $\pm$ 12.8 cm) while the average weight was 68 kg (68.4 $\pm$ 15.4 kg). All the subjects were right-handed except 3 subjects and subjects were physically active when the survey was taken. All subjects provide an informed consent (through mail) and were volunteers and were not provided any monetary compensation.

2.2 Methods

This pilot study used an internet-based questionnaire with a cross-sectional design. Self-reported responses on use of mobile devices and self-reported symptoms of pain in 18 different parts of the body for 80 subjects were collected from all parts of India. A questionnaire involving 2 sections (first section to assess psychology about smart phone usage and second section to assess musculoskeletal issues with smart phone users) was developed and surveyed among the participants. The survey was circulated among friends and relatives using Google form. A pain analysis was done in 18 different body parts of the body using RBG pain score (0 designates no pain and 5 designates most severe pain) for rating the pain.

2.3 Psychological Assessment

Psychological questionnaires were framed using well know validity standard techniques such as Problematic Mobile Phone Use Questionnaire (PMPUQ), Online and Digital Media Usage on Cell Phones among Low-Income Urban Youth in Cape Town, Smartphone Addiction Scale Short Version (SAS-SV) questionnaires, Smartphone Withdrawal Scale (SWS), Smartphone Impact Scale (SIS) [9–11]. Users opinion on smart phone usage were obtained. The participants shared the importance of smartphone, usage, addiction, their satisfaction and brand of the smartphone. Their opinions on smart phone benefits were also obtained.

Table 1 Crtiteria for pain-score and their scores

Pain-scale criteria	Pain score
No pain	0
Pain while more than average work out time	1
Mild pain	2
Moderate Pain	3
Continuous Pain	4
Severe Pain	5

2.4 Musculoskeletal Issues Associated with Smart Phone

Under this section, MSD was assessed in different parts of the body. In this survey we allowed participants to discuss topics and freely express the pain they felt while or after using the smartphone. Pain analysis were performed in 18 different body parts (right/left tips of the thumb, right/left middle of the thumb, right/left base of the thumb, right/left fingers, right/left front of the hand, right/left back of the hand, right/left elbow and lower arm, right/left shoulder, upper back and neck body parts neck, shoulders, upper back and elbows). Pain analysis were rated using RBG Pain score. Pain scale analysis was used to estimate the internal consistency that is, how closely it is related to a set of items or as a group. To estimate the pain scale Cronbach's alpha test was used. Cornbach's alpha test is considered to be a measure of scale reliability. Here, we consider three categories of Cornbach's alpha test, (i) scores of 90 and above were considered as best Score and (ii) scores between 80 and 90 were considered as better score and scores between 70 and 80 were considered as good score. Cronbach's alpha test was performed mainly to check the consistency of the collected data. Reliability of the data is found to be 0.70. Thus, the collected data falls under good reliability score. Pain analysis were rated using RBG Pain score [13]. Pain scale analysis was followed to predict the internal consistency that is, how closely it is related to a set of items or as a group. The pain-scale criteria and their scores are depicted in Table 1.

3 Results and Discussion

Statistical analysis was performed using IBM SPSS statistics software. The aim for the analysis is to find significant differences if any between the pain scores concerning different factors (Male vs. Female, smart phone display screen size etc.). ANOVA (Analysis of Variance) and unpaired t-test were performed. It is used to detect differences in treatments across multiple test attempts with level of significance set to 0.05 (i.e., $p < 0.05$).

3.1 Psychological Assessment

Figure 2 a show the customer perceptions about smart phone use. It shows that 96% population consider smart phones to be a necessity (not a luxury) for the daily living. Only 4% of the respondents think it's a luxury to use smart phone in one's daily life. Electronic gadgets play a popular role as an entertainment platform that this generation uses for spending free time and it is expected to increase in this present covid-19 pandemic situation.

The survey based on self-assessment by users results show that around 72.73% of population are addicted to smart phone usage (Fig. 2b). Only 27.27% of people said that they are not addicted to mobile phones. Regarding perception on brand name of mobile phones, only 85% of population consider brand name is very important/important/fair for buying mobile phones (Fig. 2c). From this study it is found that people consider the criteria such as brand, price, operation and basic usage for selecting smart phone.

Figure 2d shows that around 90% of respondents are happy with smart phone use. Only less than 2% of population was unhappy with their mobile phone usage. From talking to texting, smartphones are used for many purposes including internet surfing,

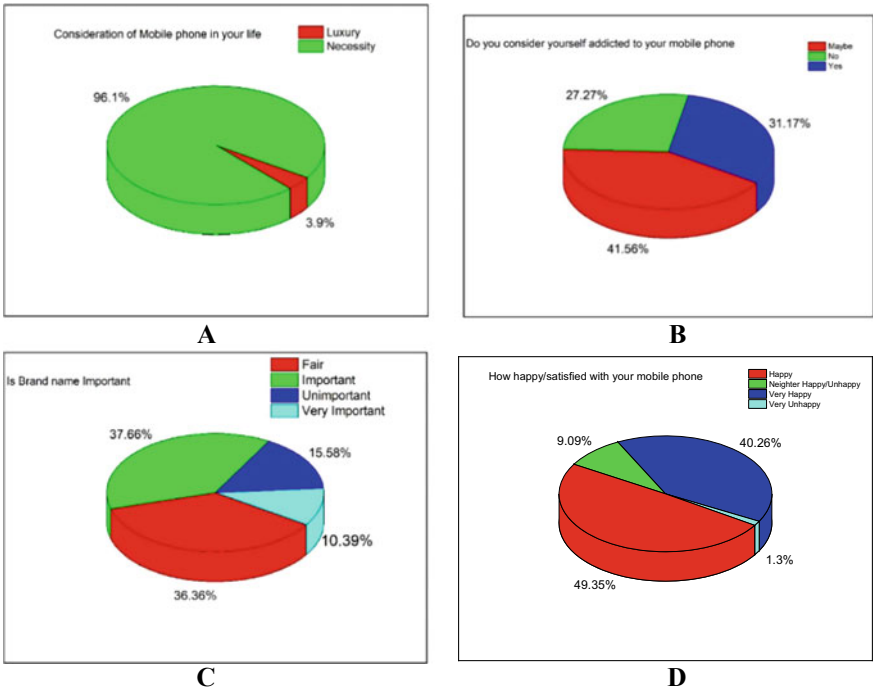

Fig. 2 The Percentage of mobile phone for the, **a** customer life, **b** addicted for smart phone use, **c** brand name of mobile phones, **d** Level of subject satisfaction about smart phone use

playing games, shopping, listening to music, getting information easily and quickly, etc. Due to Covid -19 and lockdown enforcement, smartphones are becoming an integral part of the daily routines of people, so naturally people will be satisfied with their mobile phones.

3.2 Musculoskeletal Issues Associated with Smart Phone

Usage of screen-based devices such as computers, smartphones, etc., affects our health and quality of life. Smartphones can also cause several risks such as musculoskeletal disorders, psychosomatic and community problems, headache, stress, anxiety, and sleep-related disorders. From Fig. 3a it is found that subjects who use devices with screen display sizes greater than 5.5 inches' have significantly ($p < 0.05$) mild pain in left fingers, both front of hand and right shoulder when compared to subjects using devices with less than 5.5-inch screen display sizes. Remaining body regions do not show any significant difference between the different screen display sizes. Excessive time spent on activities demanding use of large screen enhances the shoulder and neck pain. Great static strain on the hand and arm muscles may be applied when using large display size mobile (like personal digital assistants etc.,) as compared to using laptop or desktop. Considering this aspect, we conclude that screen display size within 4–5.5 inches' is suitable for ergonomic design of mobile phone device.

Gender wise comparison of MSD (Fig. 3b) shows that the musculoskeletal disorders in female have significantly ($p < 0.01$) high pain in different body regions compared to male users. Female users have significantly ($p < 0.01$) high pain in both side middle thumb, right base of thumb, right fingers, right shoulder and upper neck

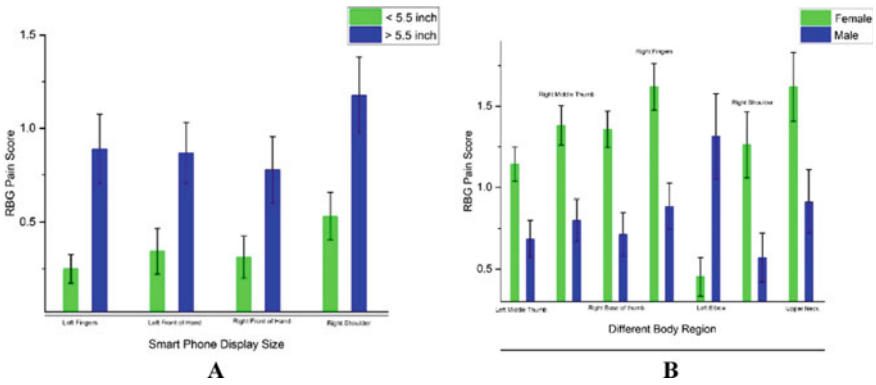

Fig. 3 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) pain score of various body region with **a** Smart phone display screen size, **b** smart phone user between male and female gender

when compared to male users. Male users have significantly high pain ($p < 0.05$) in left elbow when compared to female users.

When flexing in the flexion/extension plane, the thumb is close to 55% of its extreme range of motion, and when abducting in the adduction/abduction plane, the thumb is close to 79% of its extreme range of motion. When you use your thumb a lot in such static positions, you're putting a lot of strain on your thumb's intrinsic and extrinsic muscles.

Females demonstrated more muscle activation in the ABL and ED while text messaging, as well as faster thumb movement velocities, higher thumb abduction, and fewer pauses in thumb movements than males. The study also concludes that female users have pain in thumb and finger region which may be due the use of repetitive thumb movements leading to pain in thumb and finger region. Similarly, when using smart phones, when reading display screens, female users glance down or hold their arms in front of them. Also, total time spent when using digital devices on any normal day by female users is significantly higher than male users; the above observations could be the reason for fatigue or pain in right shoulder, and the neck among female users [2].

A study analyses MSDs associated with smart phone use. The study reported MSDs associated with shoulder—arm, head—neck and hand thumb regions. The study also finds that use of smartphones leads to MSDs and pain.

Use of digital devices or smart phones enabled with touch screens has become a common feature. Many smartphone users fix glass or plastic screen protectors to their digital device or mobile phone display screens to prevent scratches. In questionnaires itself we ask if their touch screen had tempered glass or not. In our study 62 subjects had tempered glass and 15 subjects did not have tempered glass in their display screen. Figure 4 shows that subjects who use tempered glass in their smart phones have significantly ($p < 0.01$) less pain in right base of the thumb, right fingers and

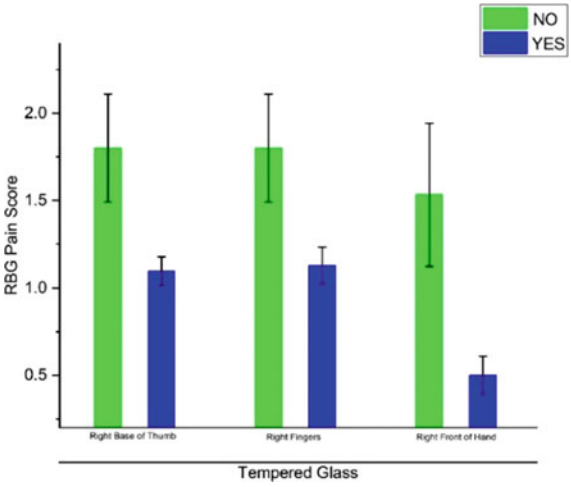

Fig. 4 RBG pain score reported on various body regions by smart phone users with versus without tempered glass

front of right hand when compared to users without tempered glass in their display screens. When using smart phones fixed with tempered glass, fingers glide smoothly over the tempered glass and it's comfortable to use. This study also shows that using smart phone with tempered glass leads to reduced MSDs compared to using smart phones without tempered glass in the screen display.

4 Conclusion

This study reveals that use of smartphones during COVID-19 times has increased drastically due to students, employees or common people staying at home and using it for their classes/work/entertainment activities. The increased duration of time spent with smart phones, overall size of the phone they handle, display size (large or small, touch) along with a decrease in physical activities leads to MSDs. The results indicate that in long-term mobile phone use will lead to MSDs in neck and upper extremities among female users. We also see that use of phones with tempered glass fitted to display results in reduction of MSDs compared to phones without tempered glass. Our study analyses the risk factors associated with smart phone usage and will be useful for manufacturers to understand how consumers select smart phones. The results of the psychological study will be helpful to understand the ergonomics aspects of mobile phone usage.

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Prevalence of Musculoskeletal Disorders Among the Agricultural Workers: A Review

Ram Charan Bairwa, M. L. Meena, G. S. Dangayach, and Rahul Jain

Abstract The agricultural occupation is considered labor-intensive because most tasks are performed manually using traditional farming hand tools. These hand tools are not designed ergonomically, resulting in excessive stress on workers and leading to musculoskeletal disorders (MSDs) in the body. This study aims to identify the agricultural risk factors associated with the prevalence of MSDs among farmers. Total one hundred and thirty six articles starting from the year 1985–2020 were searched through ePublishers (like Taylor & Francis, Science Direct and Springer) using the keywords such as agriculture, MSDs, ergonomics and productivity. Finally, thirty one articles were selected for the review study that fulfilled the inclusion criteria. Through systematic literature review, it was found that along with the usage and design of hand tools, factors like a repetitive task, awkward postures, forceful exertion, vibration, and exposure to hot weather are mainly responsible for the work related injuries among farmers that leads to severe chronic pain and work disability of workers. Lower back pain, shoulder pain, and cervical pain are the most frequent occurring MSDs in farmers, which are recognized as crucial problems in the agriculture sector that are generally neglected. Hand tool design intervention is more effective in reducing the prevalence of work related injuries in farm workers. It is suggested to apply the principles of physical ergonomics not only in the agriculture sector but also in other industries where traditional tools and working methods are being used.

Keywords Agriculture · Musculoskeletal disorders · Ergonomics · Farming · Productivity

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1 Introduction

According to the ILO report published in 2003, farming is one of the ancient and hazardous occupations in all countries globally, employing approximately 1.3 billion workers that is equivalent to half of the world's entire workforce [1–5]. More than 60% of the population (around 260 million workers) is engaged in agriculture in developing countries like India, the largest number of agriculture workers globally. Thus, it is known as the country's backbone as its primary source of revenue for a huge part of the population [6, 7]. Wheat, millets, barley, maize, rice, and oats are essential and common cereals produced in India. Today India has become the second largest producer of wheat and rice, covering a total of 140 million hectares of total cultivated land, and transformed itself from a food importer to a food exporter country [6, 8]. The prominently used hand tools in agriculture are spade/hoe (Phawra) for preparing land, ridge making and irrigation, sickle (Daranti) for crop harvesting, weeding fork (Khurpi) for weeding, pick axe (Kudali) for soil digging and rake is used for making the ridge to plant seed [9]. Usually digging earth, land preparation, sowing, weeding, irrigation, pesticide spraying, harvesting and winnowing etc. are performed in agriculture [10]. According to a research article; 66.6% of farmers have low socio-economic status as a result farming activities like harvesting, weeding and land preparation is performed manually using traditional hand tool like sickle, khurpi and spade [11]. These farm activities require a high demand of energy because of strenuous physical efforts like tight gripping, pushing and pulling tools, and exerting physical stresses at back, neck, shoulder and wrist/hand; hence, these farming activities are associated with higher MSDs [7, 12–14].

Farmers perform strenuous tasks; hence they are exposed to a wide range of occupational risks and hazards. Low socioeconomic status, poor access to health care and negligence toward safety contributes to the health problems like MSDs [3, 9, 15, 16].

It involves various farming and non-farming injuries/illnesses, among which musculoskeletal disorders (MSDs) are recognized as the most common non-fatal injuries and disorders among the farmers. The Prolonged static posture or repetitive task is major contributor to MSDs. It is responsible for the short and long term sickness, work disability, and a functional limitation that reduces the quality of life and harms the economics of individuals and the community. Therefore prevention of these disorders is the main concern in developed and developing countries [1, 2].

Among various farm injuries, 64.7% injuries (Maximum 24% from Spade + 23% from sickle + 17.7% from the other tools) are associated with manually operated farm hand tools, 29% injuries from the farm machinery and 6.2% farm injuries are from other sources like snake bites etc. [8, 9]. The major cause behind the hand tool injuries is fatigue due to repetition of tasks and slippage of tool due to sweating palms. Feet, ankle, hand, wrist, lower back, the fingers of lower and upper limbs are the most affected parts of the body from these injuries [17]. Cut and tearing of tissues due to sharp edge of sickle are the dominant work-related injuries. Sprain

and Strain occurred during digging and preparation of land with spade and pick axe [1, 2, 4, 9, 18].

It was considered that the adverse environment conditions, improper use of hand tools, lack of ergonomic consideration in hand tool design and negligence of safety measures during the working are the main sources of these agriculture injuries that cause MSDs [17]. It is essential to design the hand tools and equipment as per the operator's biological needs, body dimensions and capabilities to achieve higher comfort; lower fatigue and higher human productivity. The types of equipment/tools designed without conceiving the body dimensions of the user population will lead to higher pain, lower efficiency, and MSDs in the body [6, 15, 17–22]. The agriculture risk factors that cause MSDs are (a) static work posture (b) awkward postures like twisting and bending, stooping, squatting, (c) strenuous physical work (d) forceful exertion, and € vibration [6, 7, 16, 23–27]. When the worker's upper extremity is mainly engaged in static motion, the postural analysis is done by RULA (Rapid upper limb assessment). However, when the entire body and limbs are engaged in dynamic motion, the REBA (Rapid entire body assessment) technique is used for postural analysis. The RULA and REBA score of more than 7 indicates a high risk that requires immediate investigation and implementation of change [1, 13]. The numerous types of MSDs (pain in back and neck, cumulative trauma disorders (CTD), carpal tunnel syndrome (CTS), tenosynovitis, tendonitis, Epicondylitis and non-specific muscle and forearm tenderness, cellulites, Epicondylitis/Tennis Elbow etc.) are associated with agriculture tasks [23]. In such situations, ergonomic intervention has proven a powerful tool to reduce the MSDs in farmers, including the design of user-friendly hand tools, improved work processes, and stipulation of shorter rest periods [6, 14, 28]. MSDs occurred because hand tools can be prevented by designing the hand tools and equipment according to the operator's biological needs, body dimensions, and capabilities to feel more comfortable with lower fatigue. Thus higher human productivity can be achieved [15, 19]. Various studies recommended that the handle diameter of sickle should be 3.1–3.7 cm and the handle length to be 12.4 cm. Similarly, the weight of spade should be 2 kg, angle between blade and handle to be 65–70° and the length of handle should be 60–80 cm with the diameter of 4 cm. [8, 11, 17–19, 21, 24]. Mostly responded reported 81% pain in lower back/lumbar that is higher than upper back/Thoracic (61%) followed by Neck/Cervical (75%), Lower Extremities (65.4%), Fingers (62.1%) and shoulder (56%) [25, 26, 29–31]. The primary purpose of this study is to review major health-related problems and associated risk factors in agricultural work.

2 Methodology

This systematic literature review consists of three steps; Literature search, screening, and study assessment, as shown in the Fig. 1 flow chart. The inclusion and exclusion

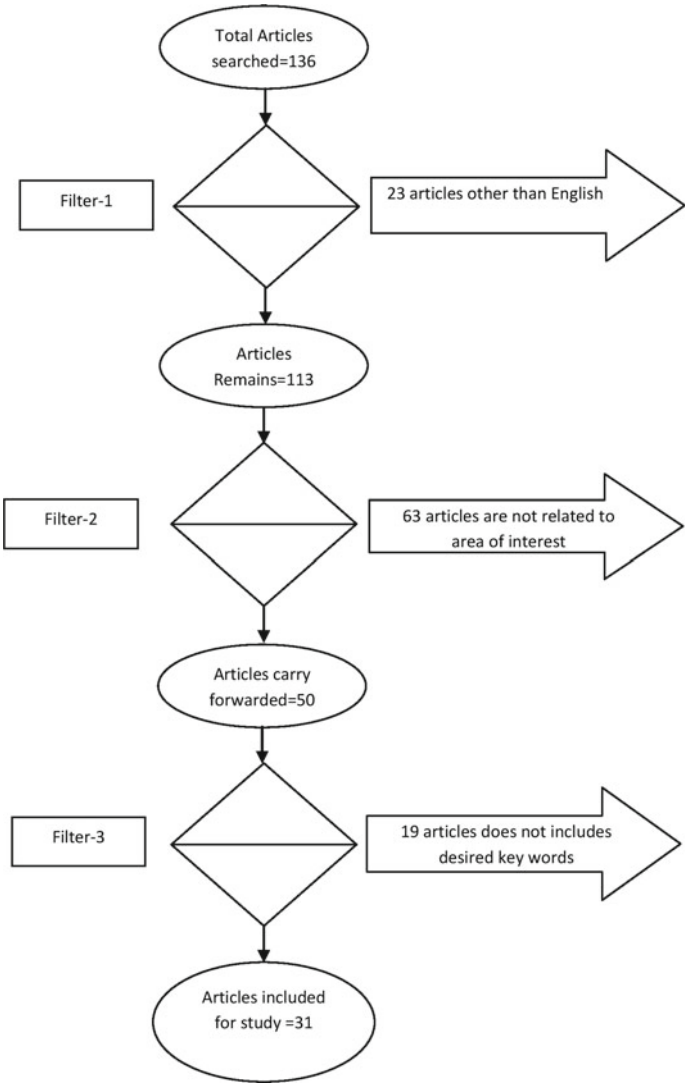

Fig. 1 Flow chart of literature review

criteria based on the keyword and area of research was formulated to find out relevant journal articles.

Step 1. Literature Search

The literature search was conducted online using PubMed, Taylor & Francis, Web of Science, Google Scholar, and Science Direct. Total one hundred and thirty six articles searched by using different combinations of keywords of agriculture workers were: Agriculture, farm worker, agriculture worker, Farmer, harvesting, weeding

and the keywords for MSDs were: Injuries, Musculoskeletal Disorders, Pain, muscle disorder, sickness, Ergonomics, Productivity. Research Publications between the years 1985–2020 in the English language were selected for the study.

Step 2. Screening of research articles
The screenings of the 136 searched articles were done in three phases. Initially, screening criteria was language of the articles. Twenty three articles that are in other languages than English was omitted. In the second phase, 63 papers other than the agriculture field were not considered for the study, and in the last phase, 19 papers that did not consist of relevant keywords like agriculture/farmer worker and musculoskeletal disorders were removed from the list. Only 31 articles that fullfill the desired criteria were selected for further study.

Step 3. Evaluation of Study
Assessment criteria (major injuries and associated risk factors) were constructed and based upon them the recommendation and further scope of work is identified.

3 Results and Discussions

The result of the literature review of thirty relevant articles is summarized in Table 1 after applying the three phases. The maximum number of articles focused on identifying risk factors, most affected body part and their preventive measures. The most frequently used hand tool in farming operations is sickle (100%), spade/hoe (92.0%), long knife (69.3%), shovel (23.5%), pesticide sprayer (19.1%), and harrow (16.5%). Both spade and sickle operation is contributing highest injuries and MSDs among these farm hand tools. Significant risk factors associated with agriculture work are shown in Table 1 that includes awkward postures (like prolonged static posture, squatting, stooping, twisting trunk, work with bending neck etc.), Manual material handling, sudden force exertion (lifting heavyweight), and exposure to sweltering weather.

Most farmers' maximum disorders or pain are in the lower back, upper back, mid back, neck, shoulders, wrist/hand, knees, etc. The major article recommended that the occurrence rate of MSDs related to farm hand tools be prevented among the agriculture workers (Male and Female) by using ergonomically designed hand tools for doing farming works. Similarly, the MSDs due to awkward working posture can be reduced by stimulating the shorter rest period and changing the working method. The lifting weight should not be greater than 20 kg while doing manual material handling activity at farm so that MSDs due to sudden exertion of force during lifting weight can be prevented.

Table 1 Agricultural risk factors and affected body parts

S.no	Body parts	Risk factors	Reference
1	Neck/Cervical	Lifting load on head Bending neck during work	[1, 2, 6, 7, 16, 24–27, 30, 31]
2	Shoulder	Repetitive motion Spading Ridge Making	[6, 9, 16, 24–27, 30]
3	Upper Arm	Static position of hand Bearing load on Hand	[2, 7, 9, 18, 25–27, 30, 31]
4	Elbow	Sudden exertion of load Pushing & Pulling	[2, 7, 9, 18, 25–27, 30, 31]
5	Wrist	Vibration	[2, 9, 18, 25–27, 30, 31]
6	Palm& Fingers	Handle design Static Gripping Usage of hand tool	[7, 9, 18, 25–27, 30]
7	Upper Back/Thoracic	Stooping Posture Squatting posture	[1, 6, 7, 16, 18, 24–27, 30, 31]
8	Lower Back/Lumbar	Heavy lifting Twisting of Trunk	[1, 6, 7, 9, 18, 24–27, 30, 31]
9	Pelvic Region (Hips)	Static position	[6, 16, 24–27, 30]
10	Thighs	Static position	[16, 24–27, 30]
11	Knees	Repetitive Bending Static Position	[6, 16, 24–27, 30, 31]
12	Calf Muscles	Moving with carrying weight Exposure to Hot weather	[16, 24–27, 30]

4 Conclusions

Through this literature review, it is concluded that a major parts (approximately half) of the total workforce of the world is engaged in the agriculture sector for their livelihood. The significant risk factors associated with farming include awkward postures, poor methods of handling, sudden force exertion (lifting heavyweight), working with traditional hand tools, and exposure to sweltering weather. Most farmers experienced high discomforts in lower back followed by neck, shoulder, and wrist and fingers, which occurred due to traditional equipment, especially hand tools and awkward working posture. These disorders reduced workers' productivity and disturbed financial planning; thus, the quality of their life is adversely affected. It is also observed that ergonomics intervention has proven a powerful tool to reduce the MSDs in farmers, including the design of user-friendly hand tools, improved work processes, and stipulation of shorter rest periods.

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Status of Political Cartoons in Indian Society: A Human Commination Perspective

Prasun Chakraborty and Anirban Chowdhury

Abstract India and Indian society and people change here lots during last 10–15 years. As the influence of digitization People changes lot, there habits also change, print media is decreasing value day by day. Unknowingly we are surrounded by technology. This study aims to unfold the status of political cartoon based on available evidences from online and printed resources such as, articles, review articles, reports, books, news etc. This research work has successfully covered the characteristics of political cartoons in print and electronic media. Where Importance of political cartoon has changed cartoonist developed technical skills. Authors of this paper analyses the human factors issues related to political cartoons to assist scholars to discover novel concepts in evolving fields of Indian political cartoon.

Keywords Cartoon · Political cartoon · Common Man · Indian news · Social impact

1 Introduction

India always blessed with countless number of talented flourishing cartoonist with political awareness. They combined their skill with good sense of humor and illustrate beautiful timeless cartoon. Those political cartoon beautifully narrate the situation and draw attention to the viewer socio-political illness like corruption, violence and other.

A political cartoon help audience to think about current situations as well as it narrates the view of target audience. The finest political cartoonist might help to alter the mind-set of target audience to an event. However, the thirst for political cartoons among newspaper readers in different languages has increased a lot since nineteenth century to twenty-first century.

Unlike many countries, India is a place where politicians actively enjoy their political career for generation after generation. In today's Indian scenario, hardly

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few newspaper like to publish or promote political cartoon. Gradually decreasing popularity of print media and currently the political cartoon in print media going through a big crisis.

The goal of this study is based on the importance of political cartoons in the newspapers in current scenarios and analyses the characterization of political cartoons. A detailed study has been conducted to show a status of political cartoons in India. In today's communication media platform, it is very significant to comprehend cartoons illustrated by the great cartoonists of India. The human factors perspective of political cartoon is also described in this article.

2 Political Cartoon

Italian word 'cartone' is the origin of the word "cartoon". It signifies to an illustration made on paper as a study for artwork. The art of cartoon is derived from 'caricature' which is derived from the Italian word 'caricare', expresses exaggeration. [1–3] In another word, the cartoon is an art form which is expressed through exaggeration and humor, and even in a satirical way, and it could reflect socio-cultural, political and economic issues. The great artist and philosopher viz. Leonardo da Vinci, Annibale Carracci and Gian Lorenzo Beniniplm, use to depict their thought caricatures. [2]

The issue-based cartoons gradually become popular after the mid-nineteenth century and started narrating various situations. These political cartoons have attained the wisdom of a pictorial parody with humor and satire. It touches an issue that may not be suited for comment by the editor. It is a visual interface that involves the audience, helps them appreciate and understand the socio-politico-economic scenarios in the country and the world. Political cartoons can be very joyful, especially if the target audience understands the issue that they're connecting with. Political cartoons can be seen on various platforms, for instance-newsmagazines, political websites, printed newspapers, e-newspapers, social media etc.

Now-a-days, political cartoons play an important role in everyday life through various communication media. [2] However, cartoons add special value to the newspaper despite advances in photography and animation technologies. The cartoon still commands its own place in newspapers. Cartoons have an ever-lasting impact on the minds of readers [3–6]. Political cartoons are inspired by the situations around the cartoonist, what he sees and believes is portrayed through the sketches which they create. A cartoonist needs to comprehend the political scenario and make a comment on the social condition. It is essential for them to make an informed decision on their cartoon that supposed to publish next day in the newspaper.

3 Methodology

The author studied different articles, journals; review papers books, etc. through the help of the internet and the university library. Google, Google Scholar, and other e-libraries were used as the search engines for this current review work. Through the study of various literature, an analysis has been conducted on the impact of a political cartoon in Indian society. Through this study, the author tries to analyze the characteristic of Indian political cartoons.

4 Characteristics of Indian Political Cartoon

Any complex situation, whether it's a war, an emergency, demonetization, or if today's COVID 19 circumstances is an Indian context where cartoonists played a larger role in expressing opinions. Where editorials and pocket cartoons were cartoonists restricted and could not present their perspectives. Past and present, all cartoonists are gifted with a talent to depict any situation with a flame of humor and a sense of laughter in it. Indian cartoonists seem to be on a pro level when it gets down to carrying smiles on the faces of the readers, be it even while depicting the situations is not positive. After Independent and especially after digitalization, Indian society has changed a lot. Indians have always been known for their unity in diversity, where the thought of diversity complicates acceptance in different cultures, which is part of the nation's beauty. The characteristic of political cartoons are presented through various illustrations of political cartoons by authors which are as follows:

4.1 Symbolism

Symbol is the visual representation of a word in a meaningful way. Cartoonists use simple objects to express concepts or ideas [2]. Symbolism works even when people are not sure about how people feel and incompetent to decide what to do and how to react to different situations (please see Fig. 1) [3].

4.2 Exaggeration

The physical features of human beings or objects are ignored by cartoonists, or they overstress those human or object features, in order to make an opinion. This is called exaggeration. Mostly, cartoonists manipulate any characteristics of a character (e.g., facial and body characteristics, and other compositions etc.) which always seem

Fig. 1 Cartoonist used many political symbols to narrate the political situation

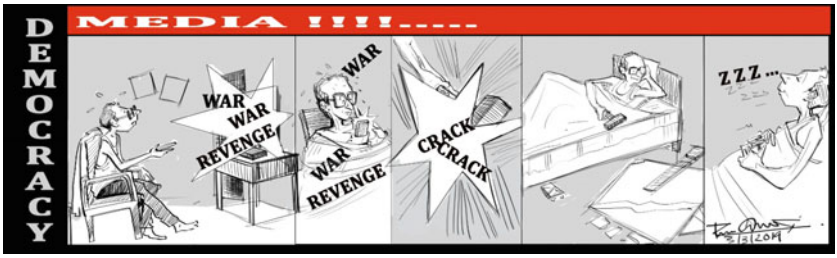

Fig. 2 Cartoonist exaggerate the situation to narrate the scenario

overdone or overblown. The cartoonists try to exaggerate the sizes of characters, emotions, and shape of a person or object for effect (please see Fig. 2).

4.3 Labeling

The element of the cartoon is often tagged by cartoonist to make it clearer for target audience, precisely what tagged elements stand for. Cartoonists execute different labels for the particular person or object or environment which appears in a cartoon (please follow Fig. 3).

Fig. 3 Cartoonist label the character through text and thaught buble

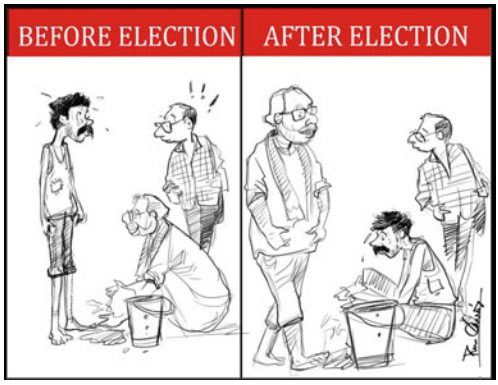

Fig. 4 Cartoonists use the same character to tell two different stories about how they act in two different situations

4.4 Analogy

The similarity in elements of cartoons can be compared based on different time frame. This is coming under analogical analysis. By associating an intricate socio-political issue or circumstances with a more acquainted one, illustrators are helping their audience to visualize different context (please see Fig. 4).

4.5 Irony

The variations between the actual situation and the portrayed situation are defined as irony. Cartoonists often use visual clues to express their opinion about ironical situations. When the audiences observe the cartoon, one can find ironical scenarios as cartoonist tried to portray in Fig. 5.

Fig. 5 Cartoonists create scenarios in which politicians twist the narrative and fool the public

Fig. 6 Cartoonists try to narrate situations through story and caricature

4.6 Storytelling and Caricature

Storytelling is common in cartoons. The cartoonist tries and explains their thoughts through stories and illustrations where the audience can connect themselves. Some cartoonist uses distorted illustrations that feature the subject in a simplified or exaggerated way, which is known as caricature; thus, story tailing and caricature both play an important role in political cartoons (please see Fig. 6).

4.7 Satire

Sometimes in political cartoons, cartoonists cannot directly attack mass leaders. In such cases, cartoonists might get life threats or be trolled by blind followers by the mass leaders. Satire is a technique where a cartoonist may highlight the truth but in a little indirect way with added humor (please see Fig. 7) [7].

Fig. 7 The cartoonist depicted the real-life struggles of a middle-class family in India during the covid period

Fig. 8 Cartoonist Charlie Hebdo drew the scenario where a character who portrayed the role of Mohamad kissing another character

4.8 Controversial Political Cartoon

One single frame political cartoon goes beyond the frame. It influences not only society, it influences political power; for example, Charlie Hebdo political cartoon in which he depicted the Prophet Muhammad as gay (please see Fig. 8). Sometimes it becomes controversial and became the cause of the death of 10 cartoonists in France [7]. Similar in India cartoonist put in jail for making a cartoon about the corruption situation in India (please refer Fig. 9) [14–17].

Fig. 9 Indian cartoonist Aseem Trivedi was arrested on charges of sedition for displaying cartoons showing India's emblem with blood-thirsty wolves instead of lions, and with the words "Corruption Triumphs" instead of "Truth Alone Triumphs

Fig. 10 Image shows suppression, oppression or emancipation

5 History of Indian Political Cartoons

The political cartoons are popularized even before the newspaper was introduced to our society. [1–9] Then caricature was an early example of "Graphic satire" (as mentioned by famous cartoonist Mr. R. K. Laxman). [9, 10] The graphic satire can instrumentally be expressed in terms of suppression (see Fig. 10), oppression (see Fig. 10) and emancipation (see Fig. 10). These three parameters allow the artist to comment on current events and political perspectives. The development of printing techniques and the evolution of newspapers in the nineteenth century led cartoonists to get their work published in the newspapers. (please see Fig. 10).

The manipulation of political cartoons into very blunt expressions may result in political power shifts or social upheaval. One single black and white or color frame once became such a danger that all leaders don't like to accept those criticisms. On the other hand, only a few political leader's welcome criticism through political cartoons. However, some situations are risky, such as the 1980s (emergency period), when none of the daily newspaper editors encouraged political cartoonists (including Mr. R. K. Laxman) to publish their work; however, Mrs. Indira Gandhi, a later Indian ex-prime minister, personally asked Mr. R. K Laxman [10] why he stopped making political cartoons on me? She also assured him that she would not interfere with his freedom of expression through political cartoons, which is why Mr. R. K. Laxman

Fig. 11 Cartoonist R. K. Laxman drew Mrs. Indira Gandhi is a powerful and arrogant woman

Fig. 12 Cartoonist R. K. Laxman captures how society is changing

[6, 7] drew Mrs. Gandhi with a sharp nose, portraying her as a very strong, powerful visionary but arrogant lady (please see Fig. 11).

Many members of sociopolitical movements use this platform to spread their message, not only for justice, but also for negative or positive campaigning. Artists such as Shiv Sena leader Baba Saheb Thackeray and R. K. Laxman [1, 2, 6] commented on various changes that occurred in independent India through their cartoons (please see Fig. 12).

R. K. Laxman once stated that the reason he stopped making cartoons was because cartoons have now become political leaders. Shankar, Kutti, Chandi Lahiri, Abuabhrham. [8, 9] India is blessed with many interesting folk stories and a strong historical background that has been appreciated by global audience from many decades. When we talk about a separate and unique zone of cartoonists, illustrators and humorists, till today, R. K. Laxman [8–10] would definitely have been one of the finest cartoonists who observed and narrated his story through his pocket cartoon every day, from 1950 to 2010, almost more than 60 years. Mr. R. K Laxman [6, 7] has been awarded with Padma Vibhushan, the Ramon Magsaysay Award, and the Lifetime Achievement Award for Journalism. Mr. R. K. Laxman designed several characters, like the mascot for Asian Paints, Air India etc., but is known for his best creation, "The Common Man", which is a symbol of all the Indian common middle

class who are speechless observers. The work of Mr. Laxman, used to appear as daily pocket cartoon under the "You Said It" in The Times of India since 1951 [8–10].

If we were to draw a map of an Indian political cartoonist's journey, we would have to include the names of Gagendra Nath Tagor and Abu Abraham [3, 6, 7] Satish Acharya, Enver Ahmed, G. Aravindan, Jayanto Banerjee, Neelabh Banerjee, Bapu (director), Kutty (cartoonist), Chandi Lahiri, R. K. Laxman, Madhan (writer), Abid Surti, Janardhana Swamy, Bal Thackeray, Aseem Trivedi, E. P. Unny, Mario Miranda [4, 6–11].

Cartoonist K. Shankar Pillai, [6–10] known as the father of Indian Political Cartoons. He started Shankar's Weekly called India's Punch (in 1948). He took Indian political cartoons to another level. K Shankar Pillai was born in the year 1902. His magazine took off in style and was always among the top demands. But the situation has changed during the emergency period (1975–1977), he had to close down his magazine and he devoted himself to create illustrations for children's books. In the year 1976, Mr. K. Shankar Pillai was awarded the Padma Vibhushan. Indians also recalled him for the establishment of Children's Book trust and the International Dolls Museum. [12]

Mario Miranda (1926–2011), Goa born, is another popular and respected socio-political cartoonist. Retrospectively, he has awarded with the Padma Vibhushan by Govt. of India in 2012. His works are predominantly published in many famous newspapers such as The Economic Times, The Times of India, and other Mumbai-based daily newspapers and magazines. Even at present, Mario's merchandising products are very popular. [12, 13]

6 Current Trends of Indian Political Cartoon Indian Political Cartoon

But today's scenario changed a lot. The main stream media is mostly moved by the ruling party, which is why asking and criticizing the government is no longer appreciated by those cartoonists who are involved in those professions. They are moved to start their own platform where they can express their thoughts, with Satish Acharya being the best example. India's most popular and talented cartoonist who established his own brand [13–16].

The best political cartoonist in India maintains a neutral stance and fearlessly narrates his message to the audience, once in newspapers and now on social media. Whether passing on messages or expressing public opinion spontaneously, the best political cartoonist maintains a neutral stance and fearlessly narrates his message to the audience.

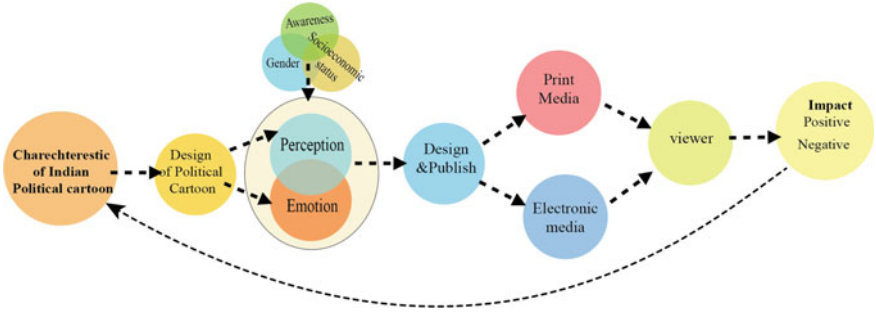

Fig. 13 Model of visual information processing of political cartoon

7 Human Factors Perspective of Political Cartoons

The cognitive human factors like perception and emotions are closely related to the political cartoons. Humour is the key element of most of the political cartoons and the humour is directly associated with human emotions. In such cases, political cartoons might act like memes and can generate various emotions among target audiences [18]. The cognitive workload is also associated with the information representation, the perception and understanding of any information [19, 20]. If the visual or verbal information is presented in complex manner, this might create problems in understanding and interpretation of information, and thus, cognitive workload might be increased in such cases. Further, the cognitive workload might increase if there is a complex representation of political cartoons leads to problems in understanding of message conveyed through political cartoon. On the other side, gender, level of socio-political awareness and socio-economic status of the target audience are influencing factors for perception of political cartoon [21]. Figure 13 represents a probable model of perceptual and emotional information processing of political cartoon considering gender, level of socio-political awareness and socio-economic status.

8 Conclusion

Through this article, authors try to capture the scenario of political cartoons in the both print and digital media, the impact of political cartoons on Indian society and the way to understand to convey the message of the current situation. Over the years, political cartoons have established importance which help to generate smiles among readers, or audience. The trend of humor has changed significantly where cheap memes have taken place, and many apps, where drawing is less important, easily convert images into illustrations. Decreasing the importance of print media, no newspapers are interested in keeping full-time cartoonists, or promoting cartoonists. The intellectual art of going through crisis, trying to figure out—what will be the

future of Indian Political Cartoon? Observations have been made on use of political cartoons for effective socio-political communication. Political cartoons might act as interface for communicating socio-political scenarios to people with or without any language barrier. Further, possibilities of understanding of situations and design issues based on political cartoons by applying digital tools and publishing on digital platforms like Facebook, Twitter and on WhatsApp, opens up new opportunities for young cartoonists. This paper also demonstrates the model of human information processing considering perception and emotion as important human factors to design political cartoons. As a result, it can be summarized that the present study will help to open up the new window for the new generation of cartoonists who want to pursue this profession to express themselves through their own design style and ideas, as well as through the use of new futuristic platforms with advanced technology.

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Gender Role Portrayal in Indian Advertisement: A Review

Partha Das and Manoj Majhi

Abstract Gender role portrayal in a communication design area of advertisements plays a vital role in shaping our behaviour to emulate or react against. In India, men and women are witnessing gender discrimination for generations, affecting the lives of both genders. This review paper focuses on past studies of gender role portrayal in Indian advertisement to comprehend the contemporary situation of gender representation. Around thirty articles have been analyzed between the years 2000 and 2020. The article and conference papers that are published in the English language have been considered for the undertaken study. Based upon the study, the magazine print advertisement shows that gender stereotype still exists in Indian advertisements. The findings of the study reveal that stereotype portrayal of gender is used in different product categories. Moreover, sexism and degrading portrayal of women are used to sell product in Indian advertisement. Some researchers also observed a slight improvement in women representation in Indian advertisements. Based upon this study, a few gap areas are identified in the study of gender role portrayal in Indian advertisements. The study also provides a platform to fill those lacunas for future researchers.

Keywords Gender-role portrayal · Stereotypes · Indian advertisements · Human factor · Cognative ergonomics

1 Introduction

The most effective form of social communication is advertising. It can manipulate the consumer by generating a wide range of personal needs and altering methods, self-image, and preferences. It's now everywhere, and because of its persuasion power, it's impossible to ignore [1]. We start our day watching weather report in the morning in our television set or reading a newspaper, in our relaxing time we read a magazine and the entire day we feed social media, youtube, Ott platform; until

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we go to bed, we watch every day thousands of advertisements. Hence we can say advertisement encompasses our life and society. Advertisers can influence people's minds only offering solutions to problems. Since advertisements in different ways have both positive and negative effects on culture, their place in society is a heavily debated subject. "It gives meaning to words and images, but how we perceive them is up to us" [2].

The Oxford English dictionary describes gender as one of two sexes (male or female), particularly when referring to social and cultural differences rather than biological differences. The term "gender" is often used more generally to refer to a variety of genders that do not fit into male and female preconceived ideas. Gender refers not just to socially created disparities between men and women but also to masculine and femininity stereotypes [3]. Gender has become one of the most common promotional techniques for product marketing, not just as a basis for market segmentation. As a result, marketing communicators should pay close attention to gender, gender-related actions, and their role in marketing communication [4].

Human factor in advertisement research is an intregal part. In advertisement audience response is frequently used to analyze human emotional reaction, perception, preference, and dislike. Gender role portrayals in Indian advertisement studies audience response by counducting experiment to comprehend audiences emotional reaction, preferences, perception, dislike about gender representation in advertisement, human interest and social construction [5–10]. In this study, our endeavour presents a systematic analysis of gender role portrayal in Indian advertisement.

2 Methodology

The systematic analysis and data collection were organized based on the key topics and empirical results of articles published in international peer-reviewed publications, and international conference proceedings.

A literature review has been conducted using the multidisciplinary scientific database Scopus, with the publication year restricted from 2000 to 2020. In the first step (primary search) of the review, the search criteria was established to account for all possible inclusion of articles/papers by selecting appropriate keywords such as 'gender-role portrayal AND Indian advertisement', 'Representation of women AND Indian advertising', 'sexual representation of women AND Indian advertisement', 'audience reaction to gender representation AND Indian advertisements' etc. After reading the titles and abstracts of the publications, the following conditions were used for exclusion: (a) no complete test available, and (b) not published in English. After reading the full report, secondary exclusion was performed with the following criteria: (c) beyond the limits of the current review and (d) data clarity relevant concern. Finally, 28 papers were chosen for the study.

3 Focus of Gender Portrayal Research in India

In Indian context, most of the articles focused on the representation of Indian women in advertisements which described their stereotyping portrayal in the advertisement. Few studies focused on the cross-cultural portrayal of gender in advertisements. Here previous researches can be generally classified into the following focus areas based on the comprehensive literature review as shown in Fig. 1. Table 1 represents the focus areas of the current study derived from selected literature.

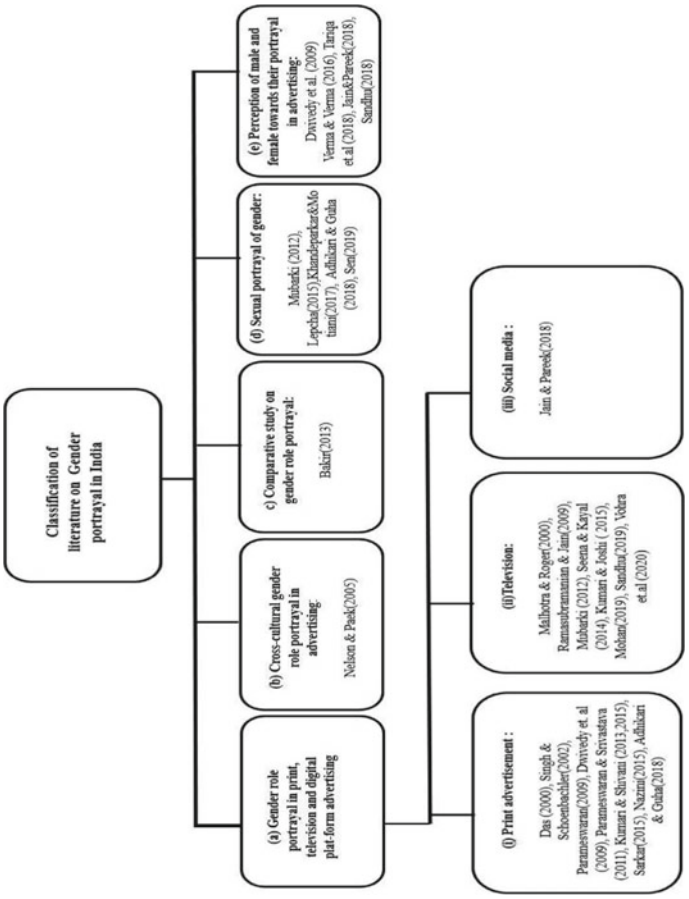

Fig. 1 Classification of literature on gender portrayal in India

Table 1 Focus areas of the current study based on selected literature

Author(s) and year	Focus of the article and Major findings
Nelson and Paek (2005) [5]	The cross-cultural study examines the transnational Cosmopolitan magazine of seven countries (China, India, South Korea, Thailand, France and United States, Brazil) to observe the level of sexuality in advertisement. The result shows that different degree of sexuality has been found in transnational Cosmopolitan magazine in different countries. It uses more sexuality in advertisement in western countries than eastern countries
Dwivedy et al. (2009a) [6]	Based upon dimensions of attractiveness, meaningfulness, and vitality, the research examines audiences' responses to print advertisements depicting male and female models in conventional, neutral, and non-traditional positions. The findings reveal that neutral portrayals are viewed as the most attractiveness, meaningfulness, and vitality, regardless of the gender of the participants. 'Non-traditional male role portrayals are perceived as lasest attrative, meaningful and vital by both men and women'[6]
Ramasubramanian and Jain (2009) [7]	The research examines conjugal desires to choose partner in matrimonial advertisement in Indian newspapers. The findings observe a social exchange in society. Financially secure men prefer physical beauty of women, demand of slim and fair girls is a common phenomena
Singh and Singla (2011) [8]	This study investigates the gender role portrayal in Indian TV advertisements. The results show women are portrayed in men's product in advertisements. They find that women are influenced by advertisements and become figure-conscious as advertisers represent thin model in their advertisement
Nazini(2015) [9]	The study examines representation of women image in Indian print advertisements. Results show stereotypes representation of women in the media unavoidably affect our culture. The young people are particularly mostly affected. The study further shows how stereotypes portrayal of women in media tend to underrate women and treat them as sexual objects as well as passive human beings

(continued)

Table 1 (continued)

Author(s) and year	Focus of the article and Major findings
Tariqa et al. (2018) [10]	This research examines different approach of women towards women's role depiction in advertisements based upon their religion. The findings show significant difference to approach toward women's role representation in advertisement of women consumers based upon their religion
Malhotra and Roger (2000) [11]	The study examines the changes of women images in Indian television advertisemet after the rapid development of private satellite in 1990. The result shows women are developing more importance in television program. Though, their characters are created generally through patriarchal and nationalist approach, gender representation progress has degraded and remains their traditional existing state. The study further finds the indication of the developing cultural hegemony in mass through India television channels
Das(2001) [12]	The reseach examines women and men gender represtation in wide range of Indian magazine advertisements in 1987,1990,1994. Findings show a slight change in gerder role portrayal in advertisement but still men and women are depicted in a sterotyepical way
Singh and Schoenbachler (2002) [13]	The western media's influence has been observed in representation of women's advertising in India. For instance, achievement and success are not associated with women, but appeals to hedonism are related
Dwivedy et al. (2009b) [14]	The study investigates gender representation of men and women in Indian magazine advertisement (2006–2007). In Indian magazine advertisements females are mainly depicted as a traditiona traditional character like mother, housewife in a home setting, busy with their household chore and obeying their male counterpart's decision. They are projected as a sexual objects to attract audience.On the other hand, men are depicted commanding position, decision maker or focusing on their career
Parameswaran and Srivastava (2011) [15]	The study examines how women role have been represented in advertising India's leading English woman's magazine Fermina in last 50 years. Results show women representation in advertisement is slow but steadily changing with increased literacy and increased emphasis on education and greater work opportunities
Das (2011) [16]	The study examines represtation of gender in three different language (Hindi, Tamil, English) of television commercial in India. The findings show men outnumber female in central character and voice over in Indian advertisements

(continued)

Table 1 (continued)

Author(s) and year	Focus of the article and Major findings
Mubarki (2012) [17]	The study examines use of sexual content in Indian television advertisements. The results show one fourth of total Indian advertisements is using sexual content. Though, sexual content in advertisements vastly is used in Indian television advertisement but foremost deriving content is emotional or argumentative. The study further shows sexual content uses women more than men, body display, sexual behaviour is used to promote products in Indian television advertisement
Bakir (2013) [18]	This comparative study observes the gender role portrayal of characters in advertisements in television channel which children watch in India and United States. The results show masculinity is predominately used in United State in advertisements than India. The study further shows advertisements target children rather than their parents in India, though it has been noticed that adults' characters are used in higher percentage as central role in India compared with U.S. commercials
Kumari and Shivani (2013) [19]	The study observes the representation of women in Indian magazine advertising. The findings show women are frequently represented in stereotyping roles in Indian magazine advertisements. For example, advertisers prefer young model for promoting brand. The study also observes a positive change in participation prercentage and the literacy prercentage of women over the last few decades in India
Sarkar (2015) [20]	The study examines the stereotyping representation of women on various products and brands in Indian print media. The results reveal that women are promoted in domestic product and hedonic product which reinforces women's representation as traditional women. Conversely, men are depicted as skilful mainly in the work setting or as the command voice of decision maker of the house, and family
Verma and Verma (2016) [21]	This paper examines the patterns in religious products advertising in India and comprehends the consumer behaviour of buyers. The result shows that the number of people following rituals strictly, decreases in 21st-century. In the last few decades, mass media show significant growth in general and especially in digital media. A lot of religious products have arisen and are easily available to people

(continued)

Table 1 (continued)

Author(s) and year	Focus of the article and Major findings
Lakshmi and Selvam (2016) [22]	The study examines gender role stereotyping of women in selected Indian television advertisements and YouTube advertisements. The study shows a positive change in urban middle-class women life due to the financial independence and the influence of the internet
Khandeparkar and Motini(2017) [23]	The study examines the emerging concept of sexism in advertisement in India. Results shows there is a misunderstanding in projecting sexual content between target group and non-target group, therefore the perception of sexism continue to be used in advertisements. The study also observes that sexual content is similarly accepted in audience if it is properly used
Lepcha (2018) [24]	The paper examines representation of women in various men's deodorants in Indian televi-sion advertisements from the year 2000–2018. The result show women have been por-trayed as disrespectful sexual rewards to the consumer in various men's deodorants adver-tisements. They are depicted as sexual beings who do not possess individual's intellect, per-sonality and morals. The study also observes some positive development since 2014; some new advertisements appeared to focus on the features of the product
Adhikari and Guha (2018) [25]	The study focuses on stereotyped, sexualized and commoditized representation of women in three Indian English magazine advertisements. Findings show media played a vital role to reinforce women portrayal as stereotypes, sexualize and commoditize. It also shows a culture in depicting females as sex objects or commodities and presents them frequently as young, slim, sexy, submissive, incompetent, and dependent on male
Jain and Pareek(2018) [26]	The study examines women and men roles in performing housework in 30 television serials from 1990–2016 and 14 old and new TV advertisements. Results show clear gender disparities between men and women in performing domestic work. This study proposes media content should be more neutral in terms of the depiction of gender roles and focus on gender equality at the micro level

(continued)

Table 1 (continued)

Author(s) and year	Focus of the article and Major findings
Sandhu (2018) [27]	The report explores the conceptual effect of gender indications in advertising on the perceived gender representations of the promoted brand. Findings confirm the major effect of gender indications in advertising on the perceived gender representations of the promoted brand The differences between men's and women's interpretations of the same stimulation is found
Sen (2019) [28]	The study examines the representation of Indian women through perfumes and deodorants advertisements. The result shows the advertisements of perfumes and deodorant body sprays often reinforce sexism and obscenity. The portrayals of women are derogatory light in the visuals, and they are depicted as the objects of sex and male desirability
Sandhu (2019) [29]	The study examines the representation of gender in television advertisements for automobiles. The result shows men are more preferable for promoting automobiles. The study further adds the automobile advertisement prefers significantly higher gender preference than non-automobile advertisements
Mohan (2019) [30]	The study examines perception on women representation in television advertisements of different age, gender, education background audiences to understand audience preference. Results show women are getting equal opportunities as men because now advertisement industry is not driven by men. Audiences prefer women as brand ambassador of social advertisements. Though, some advertisements represent women as accessories for men's product but still they are getting more respect than the past
Grover (2020) [31]	The study examines audience response of different age group on positive representation vs nudity of women in television advertisements. Results show people of different age group response differently in the positive representation vs nudity representation of women in television advertisements. The study further discusses how this sensuous representation harms women image in the society

4 Research Method Used in Gender Portrayal Studies in India

A comprehensive literature review on gender role portrayal in Indian advertisement revels that content analysis has been widely used to assess stereotypes and other advertising related isues [1–4, 11–15, 17–30]. Besides, survey and focused group methods are used by researchers to investigate audience response or reaction towards gender stereotyping in advertisements [5–10]. Some other important research methodologies are also use in gender role portrayal in Indian advertisement, for example semiotic analysis technique [32] and discourseanalysis [33] etc.

Semiotics was discovered by posing a query about one most essential aspects of human: meaning [34]. In order to analyse advertising closely in semiotic terms, audience must recognise the visual and verbal indicators in the advertisement, observe how they are structured paradigmatically, and notice how they connect to one another using multiple coding systems. Audience can presume that anything in an advertisement that has meaning for us is a sign. As a result, both verbal and iconic signs (visual representations) function as signs, adding to the overall code and meaning. These sings might simply indicate something, an object, or individuals, or they can have implications, meanings that are socially and culturally significant [32].

5 Conclusion

Over the year, Indian advertisement has stereotypically depicted gender role portrayal. Gender portrays in adverting reflect the fundamental characters of our social structure viz value, beliefs and norms. The extensive study of the literature concludes that women are mostly depicted in Indian advertisements in domestic settings with engaged household works. They are also depicted as a sex object, using their physical attractiveness to sell hedonic products. On the other hand, men are depicted in commanding and powerful position. They take important decision of the family or promotes high-value products or assets. The disparities between the two gender have been strengthening through the years in Indian advertisement which creates a stereotypical perception in the audience mind. Some studies also found a positive shift on gender role portrayal in advertisements where women enjoy more freedom and men are more corporative towards their partner.

Cognitive ergonomics aims to explain how work impacts the mind and how work affects the mind. In gender role portrayal in advertisement reseach, audience perception, emotional response, preference, and dislike are considered to comprehend audience thinking pattern or cognative state regarding gender representation. This is the the significance of gender role portrayal in the context of ergonomics.

Based on the litareture review few gap areas have been found and it has been suggested for future research. Print advertisements and television advertisements are two media where most of the works have been conducted by the researchers of

Indian advertisements. Social media advertisement and digital media have played a vital role in Indian advertisement market in recent years. Still, very few works have been found on the subject of gender role portrayal. It has also been observed that men role portrayal in Indian advertisement has not been explored that much, so this is also an interesting gap where the research can also be carried out.

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Proposed Improvisation in Gun Shooting Skills, Especially on Moving Targets to Enhance Efficacy of Shooting Training vis-à-vis Modern Day's Security Preparedness

K. C. P. Parasaram and Urmi. R. Salve

Abstract Gun shooting skills are broadly classified into two categories. Shooting at static targets and shooting at moving targets. It is a well-known fact that the degree of skill required to shoot accurately at moving targets is higher than that required for shooting at static targets. Gun shooting skills are imparted through training to all personnel engaged in security related duties, i.e. defence personnel, paramilitary personnel and police forces. Study review on the existing pattern of shooting training in vogue clearly brings out two distinct things. First, the pattern of training is largely common amongst various organisations. Second, shooting training to most personnel within the organizations is largely focused on static target firing only, excepting army. In the past few years, in the backdrop of terrorist attacks on organisations/personnel other than army, it can be deduced that all security related organisations have equal/growing vulnerability. Hence, in this context of measuring 'preparedness' of security personnel in terms of weapon firing skills required, especially for organisations other than army, a review of efficacy of existing training pattern reveals that there is an impending need to modify/strengthen the existing training pattern, so as to make it suitable/comprehensive to meet modern day's security preparedness/requirements. This paper attempts to analyze/suggest requisite modifications in existing training pattern, to identify the requisite skill set that needs to be additionally imparted in training to the soldiers/uniformed personnel, so as to make them highly competent to face modern day's security challenges.

Keywords Gun shooting skills · Modern day security challenges · Training efficacy

1 Introduction

Shooting skills have a historical significance ever since human evolution [1]. Since pre-historic times, shooting (archery) is known to have played a significant role in

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the mankind quest to hone hunting skills as well as use for self/community protection [2, 3]. During the medieval period too, across the globe, archery (shooting) is historically recorded as one of the 'prime strengths' and show of 'fighting power/prowess' amongst various kingdoms [4]. With the advent of guns & ballistics technology, gun shooting has gradually replaced archery [5]. World wars as well as many other cross-country wars serve as classic examples to demonstrate as to how gun shooting has dominated the scenario/outcomes [6]. The evolution of guerrilla warfare in certain pockets of world has further amplified the significance of 'efficient gun shooting skills' in influencing respective outcomes [7]. Gun shooting skills can broadly be classified into two categories - Static target firing and Moving (Dynamic) target firing [8, 9]. For a given distance/range, the skill set required to accurately fire at a moving targets is much different & higher than that required to fire at a static targets [9]. Static firing skills are largely applicable & useful for long-distance shooting, especially to guard against intruders from a distant boundary. Whereas, moving target firing skills are more applicable/useful in a close combat operation, when intruders try to break through a check post/sentry point or during ambush operations [10].

This study Aims to understand the requirement of moving target training in the context of modern days' security preparedness, amongst defence personnel as well as police personnel and propose a suitable system/mechanism for improvising the gun shooting skills on moving targets so as to further improve their preparedness.

2 Review of Existing Weapon Firing Training in Vogue

In India, Defence Forces, i.e. Army, Air Force & Navy, guard against external threats, while the Police Forces are responsible to guard against internal threats and also to ensure internal law & order. The central police forces (para military) serve as augmenting forces for both, defence as well as for state police personnel [11, 12]. From the view point of 'security-preparedness', gun (weapon) shooting skills are extremely significant for defence soldiers as well as for all other uniformed (police) personnel alike [10]. A study review of existing weapon training in vogue was carried out for armed forces and the same was compared with that of in police training academies [10, 13]. The following common facts were noticed.

(i) Weapon firing training is initially imparted during initial induction phase. After completion of probation and joining regular service, continuity training is provided in periodic phases at regular intervals.

(ii) The weapon training pattern/philosophy is largely similar amongst defence forces as well as police cum paramilitary forces, but with little variations from service to service, tweaked to suit respective organisations.

(iii) Except for skill upgradation/retention, continuity training during regular service period is more of repetition of whatever is taught during induction phase. There is very limited scope for acquiring newer skills or exposure to

newer things, other than those taught during training days. This is considered a significant lacuna in terms of continual improvement.

(iv) Last and most significant, barring few 'eligible' personnel specially selected for Elite Forces such as Commandos/Garuds/National Security Guards (NSGs) and equivalents, weapon firing training for most personnel of the organisations, is largely focussed on Static target firing only. Only the 'elite/special forces' personnel are imparted firing training on moving targets.

However, Army was observed to be quite advanced in comparison to other sister services in the context of moving target firing. It evolved during study review that unlike most other services, (Air Force, Navy, CRPF, CISF, State Police, etc) many soldiers of army are trained/exposed to moving target firing by virtue of jungle warfare training imparted to them during their regular service period (Not abinitio). Thus, significantly large number of army personnel are trained/exposed to moving target firing vis-à-vis their equivalent counterparts.

A pilot survey was conducted with some of the training establishments associated with weapon firing training in North East Region - Assam Police, BSF/CRPF (NE Region), Army Cantonment Guwahati Region, Air Force Station Guwahati. Feedback was obtained from these institutional heads/reps through a structured questionnaire with respect to availability and necessity for training on moving target firing practice. Feedback received largely matched with the study review carried out. Gist of feedback obtained is as appended below:

(i) Moving target training is NOT available and Not part of training curriculum for all personnel–except in case of army as explained above.

(ii) Ability to fire accurately at moving targets is considered an essential skill in the context of modern days' security-preparedness.

(iii) Imparting moving target training can play a significant role in improvising soldiers' firing skills especially on moving targets.

3 Threat Perception - External and Internal: An Overview

Similar to many countries around the world, India too has its share of sufferings from security threats, both external as well as internal [14, 15]. These threats have posed serious and perennial challenges to all security/uniformed personnel in terms of their preparedness as well as their ability to effectively handle/counter such unwarranted security situations.

With specific focus on external threats, since independence, defence forces were always engaged to protect the country from external threats, one after the other. Having had to face full-fledged wars in the first two decades after independence, our defence forces were largely focussed on conventional war preparedness. However, with changing times, the 'attack strategy' by enemy has changed to proxy war mechanics. Localised surprise suicide styled (fidayeen) attacks gradually replaced full-fledged wars [16, 17]. The aim of these proxy war mechanics was primarily

to inflict damage to security forces through frequent & localised attacks vis-a-vis full-fledged wars and in turn affect their 'morale'. Thus, our security forces were challenged/required to 'additionally prepare' themselves to counter these proxy-war tactics/localised surprise attacks over and above the conventional war preparedness [18].

On the domestic front too, police personnel in certain states/pockets were constantly engaged to counter/thwart insurgency operations by naxalites/maoists. The police forces were constantly engaged to handle growing internal security concerns/issues. Especially in the last 7–10 years, domestic (internal) threats too graduated towards suicide styled ghastly attacks on police personnel with similar aim, i.e. to instil fear amongst security (police) personnel and affect their morale [10, 19]. Thus, police forces also realised the 'need for preparedness' to counter suicide styled localised surprise attacks over and above their conventional duties/preparedness.

4 Security Preparedness in Modern Day's Context

Localised, surprise, suicide styled (fidayeen) attacks have become the trend of modern days' security threat, both external as well as internal. In all such close combat cases, the 'effectiveness of response' of security/police personnel in countering such attacks largely depends upon their swift response as well as their ability to fire accurately at attacking terrorists/rogue elements [19, 20]. Though it is a known fact that special/elite forces are specially trained to handle/counter such attacks, it is also important to note that, in all such attacks, Commandos or Special Forces personnel can come into action ONLY after few hours after 'occurrence', i.e. only after certain time lapse. Till the time special forces arrive, the onus to counter such attacks lies on the front-line foot soldiers, i.e. the first line of defence - the security guard(s) on patrol and/or the guard(s) guarding the post. Hence, in modern day's threat perception, it is considered highly essential that all soldiers/police personnel in the first line of defence should be competent enough to fire at attackers/infiltrators so as to counter fidayeen styled attacks or atleast thwart/hold ground till the time Commandos/Special Forces personnel come and take over the situation. This aspect is highlighted in the context that, in modern days' security threat scenario, it is not just army alone which is vulnerable for such attacks but also all other equivalent organisations involved in security operations. Pathankot air base attack of Jan'16, Pulwama attack on CRPF jawans in Feb'19, maoists attacks on Chhattisgarh police personnel in Apr'21 are towering examples to be noted.

5 Result and Discussion

5.1 Need for Training Review vis-à-vis Modern Day's Security Threats

From the above, it is clear that ability to fire accurately at moving targets in close combat situations (fidayeen styled attacks) is essential not only for special forces but also for every foot soldier who constitutes the first line of defence. Since Army soldiers are better trained/exposed to such situations, this is more significant in the context of all other personnel of security-related sister services including police. In the context of close combat shooting, the attacking terrorists/insurgents can be considered equivalent to moving targets. To obtain firing accuracy on moving targets, static target firing practice alone is undoubtedly inadequate. Hence, from the point of view of 'preparedness' of soldiers as well as police personnel, especially the front-line foot soldiers, to effectively handle/counter such attacks, it can be said that weapon firing skills/accuracy, especially on moving targets plays a significant/decisive role. Whereas, from the study review of existing training in vogue as well as from feedback obtained through questionnaire, weapon firing training for most personnel, except in army, is largely focussed/limited to static target firing only. Hence, it is considered necessary to review the weapon firing training curriculum with specific focus to improvise firing skills on moving targets and thus, in turn, be adequately prepared for modern days' security threats [20, 21]. It is to be noted that, even in army, exposure to moving target training is only during regular service by virtue of jungle war fare training, NOT during abinitio training.

5.2 Cost Factor - Feasibility to Impart Training to All

Another important aspect to be considered is feasibility of imparting this training (moving target) to all personnel of all security establishments, in terms of cost to be incurred. It is a well-known fact that infrastructure set up required to impart moving target training, for indoor as well as outdoor, is highly demanding in terms of suitable location & building, equipment/machinery, laser guns & targets, sophisticated software, maintainability costs etc. and as such is very expensive. Hence, existing moving target training infrastructure is developed/established in select (limited) locations only in which the Special Forces and army personnel are trained. The degree of skill imparted (firing efficiency/accuracy) in these training institutions is of very high order. However, it is to be noted that such exceptional skill level is considered not as much required & not feasible at front-line foot soldier level.

Defence/police personnel of different security-related organisations are posted to/working at numerous field stations spread across the country. If all these front-line foot soldiers are to be trained on/exposed to moving target training, it amounts to setting up numerous 'work-stations'/infrastructure to impart moving target training

to all. Cost is obviously a huge hindering factor. Hence, to make it feasible, there is a need to evolve a cost-effective method, i.e. a method/mechanism through which moving target training can be imparted to all without the necessity of setting up the existing huge infrastructure as mentioned above. Towards this, one of the practical & implementable methods is to design/evolve a suitable method/mechanism which can impart moving target training using existing infrastructure.

It is a known fact that each/most field stations have a small-arms open firing range (25/50 yards) in which static firing is practiced. Hence, if a method/mechanism be designed/evolved that can impart moving target training using the already existing infrastructure, cost factor (hindrance) is automatically resolved/overcome. It is not exaggeration to state that, mere exposure to moving target scenario to all front-line foot soldiers, i.e. the first line of defence, coupled with hands-on experience to all of them, in itself can be considered as an appropriate step towards improved preparation to handle/counter against surprise attacks and thus enhances the deterrence value of front-line defence, even if it does not impart high degree of firing skill, comparable to that of special forces. Hence, it is stated that the main purpose of this 'to be designed' system is to provide ample exposure to moving target scenario to all personnel deployed in front/first line of defence so as to make them better prepared to face/handle such situations more effectively.

The above discussion arrives at the conclusion that a cost-effective methodology/mechanism is the need of hour, that needs to be devised, through which moving target training/exposure can be imparted to all personnel of first/front-line defence so that 'security-preparedness' is further improved and in turn enhances the deterrence value of our first/front line of defence.

5.3 Identification/Analysis of Moving Target Training Requirements

In any training programme, there are two fundamental aspects - content of training & methodology of training. Methodology is deduced based on content. The same is applicable for combat related training programmes too [20]. In weapon firing training, accuracy of firing is the 'content of training'. The 'methodology' to obtain this 'accuracy' is different for static and moving targets since they are understandably completely different contexts/situations all together. Hence, for moving target training, it is first, important to analyse/establish the 'content of training', i.e. various types of target movements for which training needs to be imparted so as to enhance firing accuracy (on moving targets). This is further to be followed up by deducing suitable 'methodology of training' through which firing accuracy of soldier/police trainees can gradually be improvised/enhanced through a well-structured training programme.

The fundamental purpose of this proposed moving target firing training is to improve firing accuracy in close combat situations such as security breach or ambush

operations, specifically at the first line of defence. For this purpose, a number of articles & videos, available in the form of documented evidence in media reports (govt documentaries, govt released media reports, google, you tube, etc.) associated with such operations have been studied/observed. The focus was to analyse various types of movements of attackers while approaching a security/check post, (with an intent) to attack or to flee away (from post) after attack or when counter-attacked. The analysis has been carried out from the view point, to identify the requisite skills, soldiers/uniformed personnel on the front (first) line of defence should possess, so as to be able to retaliate such attack(s) effectively. The following commonalities have been observed.

1. Attacker runs-in towards a post from a distance in a vehicle, akin to horizontal/diagonal motion. Escapes away from the post in similar way after attack. Thus, the soldier/police is required to fire in a horizontal/diagonal direction.
2. Attacker slithers/slides from top of a tree/building, where available, akin to vertical approach. Hence, soldier/police is required to fire in a vertical/diagonally vertical direction.
3. Attacker approaches the post from a stair case, akin to inclined path approach and/or escapes away, after attack, in similar way. Hence soldier is required to fire at the enemy/target moving in an inclined path.
4. Attacker closes in towards the post covertly from one hide-out to the other, by taking cover of trees, cars or other opaque objects available in the approach path. This movement can be considered akin to flash appearance and disappearance. In all such cases, soldier/police is required to fire at enemy/target, only when visible.
5. Lastly, a group of attackers move randomly towards the post to be attacked, from multiple directions, with an intent to simultaneously attack or flee away from post after attack, randomly in multiple directions, with an intent to escape. Thus, from the point of view of a soldier/police required to retaliate, he is required to frequently change his aim (to shoot) randomly, to multiple points, from where ever the attackers are coming or escaping. Also, this random aiming is repetitive, within a specific range of direction from which the attackers run-in or run-away. Hence, this motion is considered akin to random oscillatory motion.

From the above it can be deduced that, fundamentally, there are five possible varieties of approach or escape of an attacker:

1. Horizontal Motion - straight or diagonal
2. Vertical Motion
3. Slant or inclined Motion.
4. Flash Appearance & Disappearance.
5. Random Oscillatory Motion.

Vertical motion can be considered as part of horizontal motion because of the fact that, a firer who is trained to track an object moving horizontally or diagonally, naturally & gradually gains capability to do the same in vertical direction also by virtue of inherent/in-built psychomotor skill co-ordination [22, 23].

Thus, through a comprehensive analysis of various attacks and attackers' movements, the content of training for moving target firing is thus arrived at/deduced, which fundamentally constitutes four different types of target motions - Horizontal, Diagonal, Flash appearance & disappearance and Random motion. Soldiers/police personnel need to be trained to shoot at moving targets with above mentioned movements so as to make them competent/effective to retaliate any such attacks.

It is to be noted that there are many other factors that play a major role in such attacks, such as, number of attackers, speed (mode) of travel, element of surprise, mis-leading or deceptive tactics, back-up support, etc. However, these factors are NOT taken into consideration for study in this paper.

6 Limitations and Future Scope

In moving target firing training, the primary factor is to ascertain the content of training, i.e. various types of target motions on which training is to be imparted. Having established the 'content', the methodology of training and other associated attributes such as infrastructure required, training curriculum, skill gradation criteria, etc. need to be deduced subsequently, which itself is an enormous & comprehensive task in itself. This may either be derived based on already established model for static target training or may be deviced newly/differently. However, the scope of this paper is limited to identifying 'content of training', i.e. various types of target motions on which moving target is to be imparted, so as to improvise firing accuracy on moving targets. The methodology to achieve this is not included in this paper. Further, while the content of training is as proposed above, the effectiveness of imparting this training depends on various factors associated with training methodology such as conditions of training, speed(s) of target motion, training environment, training conditions - simulated/real, inducing competitive spirit through skill gradation, etc. The independent & collective effect/impact of all of the above-mentioned factors on training are also NOT included in the scope of this paper.

7 Conclusion

Suicide styled localised surprise (fidayeen) attacks is a growing menace of modern days' security concerns. In this context, the attackers/infiltrators can be considered as equivalent to moving targets. Front line foot soldiers guarding security posts and/or on patrol duty are the first ones required to handle/counter any such attacks, till the time augmentation pitches-in. Hence, as a part of security preparedness, firing accuracy of front-line foot soldiers, on moving targets is of utmost importance. While the elite/special forces and soldiers of army are considered adept in moving target firing, the same is not true in case of most other personnel of sister concerns engaged in security, as brought out in study review. With growing vulnerability of all security

related organisations, firing accuracy on moving targets gains more prominence, especially at the level of front/first-line of defence. Hence, inclusion of moving target training in the weapon firing training curriculum, is considered highly useful to further enhance 'security-preparedness', in terms of handling/countering such threats, in respect of all security related personnel including para military & police forces. Exposure to moving target training at ab-initio stage and frequent exposure through repetitive (periodic) training, is considered to decisively and significantly improve the firing efficiency/accuracy of all personnel engaged in the first line of defence and thus in turn enhance the deterrence value of our security forces. This paper discusses the 'content of training' that needs to be considered for inclusion in training. Methodology to impart training and associated aspects are out of scope for this paper.

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Sustaining Heritage Culture Through Visual Narrative Design

Yendrembam Suresh Singh and Bhaskar Saha

Abstract In the Northeast India, certain heritage places need reanalysis for the classification of being an important historical place. Even though, the north eastern states has been bestowed with natural scenic landscape and rich cultures, little has been known to the outside world about the psychological and historical events of its local heroes who sacrificed their lives for the little paradise. The paper aims to explore one of the cultural heritage sites and focus on conveying the information through a visual narrative art form and it might support if the story of the legendary warriors is communicated through visual representation. The paper investigates through field survey and visual design implementation to sustain the historical facts along with the preservation of the heritage site.

Keywords Khongjom war · Kongjom parba · Anglo-Manipur · Design heritage · Cognitive thinking · Indigenous art

1 Introduction

The sustainability of cultural heritage development should have a standard that includes the values, aesthetic design, and legacy being united as a complete whole. According to Welch, Heritage is made present based on the past and individuals treasures such things which have been held in great esteem since preceding ages. We have acknowledged heritage as blessings from the individuals who preceded us and is our bequest of land, language, environments, information, and culture [1]. Soerjoatmodjo in her studies also mentioned heritage as preservation and an exceptional sense of belonging [2]. Andreu discussed heritage values as the significances and ideals of individuals or masses bestow on legacies like collections, buildings, archaeological sites, landscapes along with intangible expressions of culture, such

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as traditions [3]. So, heritage is things that have been continuous with us and its set of experiences ought to be investigated [4].

2 Classification of Cultural Heritage and Importance of Preservation

The world heritage has been classified into two categories under the "World Heritage Convention" as 'cultural heritage' and 'natural heritage' based upon the natural progression or the outcomes of human activities. Under the category of 'cultural heritage', there comes monuments, architectural works, sculpture and paintings, inscriptions, etc. and buildings, architecture with their homogeneity or place and sites valued from the historical, aesthetic, ethnological or anthropological perspective [5]. Labadi discourse about heritage as a building block for sustainable development and is a reminder of the ties between culture, nature and societies in today's changing world [6]. Cultural heritage is a diverse but a source of reminiscence and motivation that contribute to national and local community identity-forming the principal sense of habitation and unity [7]. Vecco also argued that the idea of cultural heritage selection which was based on historic and artistic values should also include the cultural value which is the value of identity and the capacity of the object to interact with memory [8]. Most heritage sites carry dissonances due to inherent anachronisms that result from conflicts of specific communities as can be seen from every site with contrasting narratives being attached and grounded in history [9]. Thus, there is a strong need for preserving the cultural heritage in a precise and justifiable way for our future as well.

The investigation of values in cultural heritage is significant because the primary objective of most of the heritage sites is the conception or solidification of the country-state, its cultural identity, and collective memory [6]. Improving and advancing the social information of the visitors by exploring novel ways of investigation and communication technologies are being taken up by archeological parks, museums, and social establishment [10].

2.1 Existing Techniques of Cultural Heritage Preservation

There has been studies on the areas where concepts, pedagogies and different mediums being investigated and explored by researchers for the preservation of the cultural heritage in a meaningful way. Palombini attempted a theoretical framework for storytelling set up for cultural heritage and recognized that anything conflicting with historical documentation should be avoided and preference should be given to the simplest dynamic to fill the gap between known events [11]. It is a basic yet

effective way for better communication. Valtolina additionally depicted the storytelling objective as a spreading incorporated cultural heritage that enhanced, enrich, maintain and upholds the social-cultural knowledge itself [10]. Soerjoatmodj [2] also discussed that the use of storytelling sessions in her study where the sources of information comprise factual information about the artifacts along with their historical contexts. Marmion also in her examination described the need of developing a long stint with more engaging ways of heritage narrative, resulting in an understanding of the meanings and values beyond the personal level of the heritage viewers [12]. In view of the Marshall McLuhan famous adage that 'the medium is the message', the medium will often impact the way a narrative is told, distributed, and experienced, Kalliopi Kontiza and the team also explained and discussed the sustainability of the storytelling and use of narrative panels as one of the features in the CrossCult application [13]. Kolay described uplifting craft guilds and revitalize cultural heritage awareness by adopting new media as a tool with a meaningful designer intervention in Indian traditional art and craft practice [14]. The medium, although can be digital but should be a communicative and cognitive unity endowed with form and meaning [15].

Thus, it tends to be accepted that different methodologies are being investigated so saving social or cultural heritage stays encompassing and support the trustworthiness of the site with its chronicle realistic and foundation. E-learning, Infographics, catalog and brochure and so on are various mediums alongside new media advancement which are utilized for correspondence and based on the information.

3 Research Gap

Various investigations have been explored in the development of cultural heritage for sustaining the values, although an efficient and simplified way can be introduced by using visual representation or comic which is also one powerful medium for effective communication. Paintings, murals, sculptures, inscription, etc. are some of the know examples in most site, but still, a more convenient approach might be possible using the visuals with narratives. The gratification of the visitors in relation to the cultural heritage and the realization of the peculiarities and historical fact through the medium is what these study searches for.

4 Aim and Objectives

Aim of the study is to explore, identify and develop a Visual Narratives Design (VND) for effective communication in conveying the historical information of the heritage site.

The objectives of the study is to design a framework that will establish or strengthen the cultural identity and traditional value of the place. The study further explores the backgrounds and implement the design thinking for which will have an impact on the visitors and others in better understanding and gain knowledge with an enduring impression.

In this context, one cultural heritage site of India's north east region of Manipur was selected for the exploration and in depth analyses for developing a sustainable way and representation of history through the VND for better communication.

5 Design Framework

The research design approach framework for the study is shown in Fig. 1 below. The study was carried out in two- phase in which the first phase started with the exploration of the site and identifying problematic areas which were validated through a survey and analysis of the result. Afterward, in the next phase, there were collection and finding of the actual historical information, discussion with locals and experts for the development of the Visual Narrative Design (VDN). A prototype was developed and tested through online platform interviews and discussions and validated.

6 Pragmatic Approach

The north eastern states of India comprise of eight states is a region with a rich cultural diversity and natural heritage sites inhabited by different ethnic groups of people (Fig. 2a). Manipur is one of the states which is endowed with unique custom, tradition and history. Some of the popular heritage sites in Manipur includes Kangla Fort, INA Memorial, Imphal War Cemetry, Khongjom War Memorial Complex, etc.

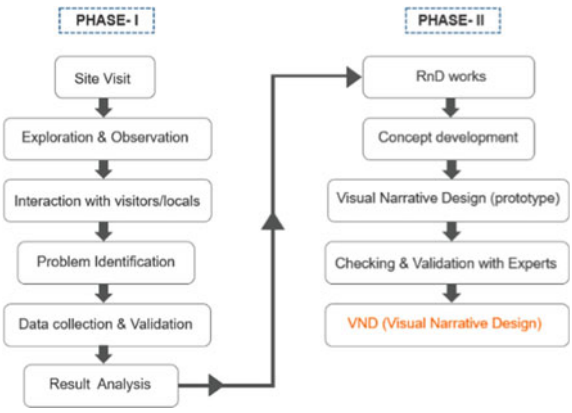


Fig. 1 Framework of experimental study

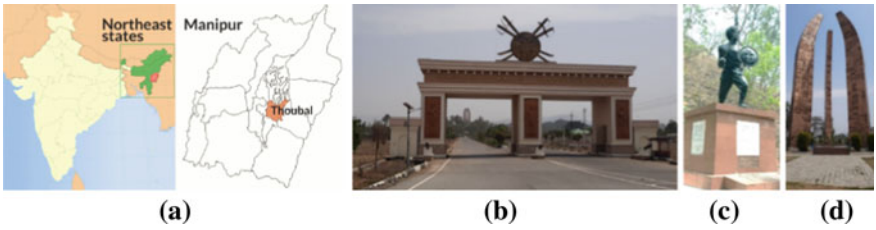


Fig. 2 India map and Manipur state [19, 20] and site specifics photographs of the Khongjom memorial war complex in Thoubal-Manipur

among others [16]. Each of the sites is well maintained and renovation works are also still in process for protecting and preserving the cultural heritage of the place. These sites have a historical significance and are the essence of Manipur keeping the traditions and cultural values alive. There is a tendency even in Manipur literature in the pursuit of self-identity for deepening the awareness of its national culture [17]. However, due to modernization and the restoration/renovation of structures and landscapes, missing context is visible in some of the sites. For the study, the importance of conveying the historical information is taken up where visitors felt while visiting such historical site which will sustain the cultural and traditional aspect of the future generation.

6.1 Experimental Study

The site chosen for the study is the Khongjom War Memorial Complex, which is located on Kheba Hill in the Thoubal district of Manipur, around 33 km from the Imphal, the capital of the state as shown in Fig. 2a. The site is related to the event of the Anglo-Manipuri War, 1891, and is one important historical place of the state. The Complex is one of the popular Cultural Heritage sites and is a major tourist attraction place. The Government of Manipur had conducted a concept drawing competition and invites Architects/Artists/Students to submit concept designs for - Construction of an Anglo- Manipuri War 1891 (Khongjom War) Memorial Tower at Kheba Ching, Khongjom, Manipur [18]. Thus presently, Khongjom War Memorial Complex has a very new renovated look. People visit the area to pay homage to the local heroes that laid down their lives in the Anglo-Manipuri War, 1891 which is called the Khongjom Lan in the local dialect, "Lan" is "War" in the English language. While there are others too, who visit to have a glimpse of the scenic and renovated look?

The site was chosen especially for its historical background which is very important and also people from different areas visited the place at large number due to its renovated look while others to pay tribute. It was necessary to find out whether the visitors are able to get relevant information.

The present look of the Complex is shown in Fig. 2b. Khongjom Entrance gate, Fig. 2c. Statue of Major General Poana Brajabasi at foot hill, and Fig. 2d. Monumental Shrine at hill top.

There are also other attractive areas inside the Complex, which are developed for tourist attraction and hence not covered in the study. The huge monumental structure at the hill top symbolizes the valour and courage of the freedom fighters of Manipur, who fought against the three sides of the British attack in the Anglo-Manipur War, 1891 [21]. The present look inside the Complex is mesmerizing due to the scenic surroundings and the newly constructed artefacts and other developments jointly by the tourism dept. of Manipur along with the state government. Visitors from all places came every day, which includes locals, outside the state and foreigners.

Even though the war memorial has been constructed in the name of great warriors and "Khongjom Day" is observed every year on the 23rd of April in Manipur, the majority of the visitors lacks the understanding and the problem of conveying the information is visible. The beautification is a part of the design heritage, yet the historical information lies hidden beneath the layer of embellishment.

6.2 Data Collection from Visitors

There were 56 numbers (n = 56) participants who joined in the survey experiment which includes the visitors, local people, and experts. A total of nine questions was used for the investigation process. The first three questions, investigates about the visitor's interest in the historical background and view of the newly design Complex. The next three questions were to validate if the visitors know the actual events of the past while the last three questions, queries if alternative solution to bring out the historical information can be helpful.

The field-work study started with a visit to the site and explore the area and it was observed that the historical background information is not available for visitors. There was interaction with the local people to know the ground reality and also a survey was conducted to validate the problems. The visitors include both the local people belonging to the state and also from outside the state. And presently, there is no scope to access the information in the complex. The collection of data through survey of visitors is shown in Fig. 3a, b.

Fig. 3 Data collection from visitors inside the Khongjom War memorial complex

After result analysis, it was found that visitors lack the historical information. So, there was a collection of the facts and related information about the event. Based on the resources, a story in shortens form was developed keeping the important phases on account of history only. Visual development was done along with the panels, textual layout in the following stage. There was also discussion with local people, and experts for the factual information. The story in brief about the Khongjom War based on sources describes as follows-

Manipur, earlier known as Kangleipak, was an independent princely state lying between the British India to the west and Myanmar (earlier known as Burma) to the east. The tiny independent state was a barricade for the Burmese expansion, but the downfall of the Burmese empire in the third Anglo- Burmese War in 1885 and internal crisis among the princes after the decease of King Chandrakriti in 1886 gave the opportunity to the British to interfere with the state. In March 1891, five British officers were killed inside the court premises in Imphal. To avenge the deaths, three columns of British troops attacked Manipur from three sides on April 1981- from Cachar in Assam, Kohima in the Naga Hills, and Tamu in Burma. The Tamu column, which marched in from Burma was met with heavy resistance in Thoubal and it is known as the Khongjom War or the Anglo-Manipuri War, 1891. Major General Paona Brajabashi was one of the commander who was giving stiff resistance against the outnumber and well equipped British troops and despite fighting valiantly, the Manipuri army eventually perished against the superior might of the invading British Army [22].

6.3 Visual Narrative Design Development Process

After the story is finalized, relevant references (Fig. 4a–d) were collected for the visual development and the prototype of the design was created for testing and validation.

Figure 4a is an old painting which depicts the event of the Khongjom war event by renowned artist, R.K.C.S and a portrait of Major general Poana Brajabashi in Fig. 4b and the traditional Manipuri warrior customs in Fig. 4c is shown. A photograph of

Fig. 4 References [23, 24] and, a photograph inside the Kangla for visual development

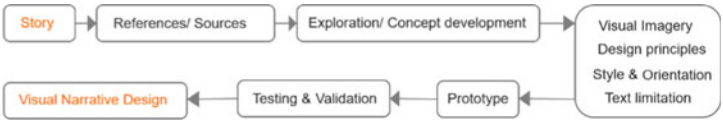


Fig. 5 Process of VDN development

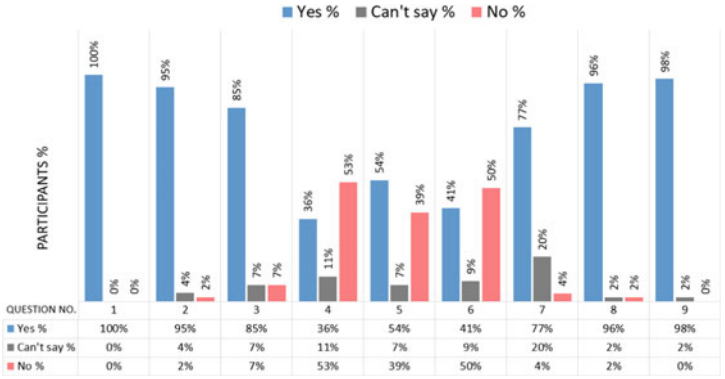
the reinstate Kangla Sha of the Uttra - the coronation hall in the Kangla Palace is shown in Fig. 4d.

The prototype VND consists of four pages with 15 panels (Fig. 7) and is a scenic representation of the event with a short description which will allow viewers to get an immersive content of the historical events. The design is similar to a comic strip, but here the collective use of a single narrative is used for multiple frames at times breaking the traditional style of a normal comic strip where captions along with speech or thought balloons are used separately for individual frames. The details of the design process are showed in Fig. 5.

6.4 Result and Discussion

In the survey conducted on the site, there were n = 56 participants and nine questions were used to understand and validate the problem that was observed. The first question was asked if they would take interest in knowing the history of the heritage site and there were cent% agreed on it. The second question inquired whether the makeover of the Complex is attractive and preserves the cultural value to which 95% agreed. In the third question, the opinion about the initiative of the Govt. Of Manipur had taken up in organizing concept competition for the construction of the site was raised and 85% supported the move. The fourth question was to examine if they have known the Khongjom War event of 1891 and here 53% were negative and only 36% were positive while 11% have little knowledge. The fifth question was asked if they know Khongjom Parba which is an indigenous ballad song that narrates the event and 54% know the art form, 39% have no idea and 7% cannot say. The sixth question was queried whether they know about Major General Paona Brajabashi and 50% of the participants do not know while 9% have no answer and only 41% actually knows. In the seventh question, it was inquired whether they feel that the design elements inside the Complex are nice, but there is a lack of historical information to which 77% agreed. The eighth questioned about the idea of visual sequences like a painting in series/illustration or other static sequences inside the Complex for the historical facts and 96% likes the idea. The ninth question discussed the preservation and protection of the heritage site with relevant information to which 98% agreed. The graphical representation of the survey is shown in Fig. 6.

It was evident from the survey that the historical information on the site remains invisible to the visitors. After the analysis of the survey, the next step of validating the effectiveness of communication through the VND was taken up through qualitative



QUESTION NO.	1	2	3	4	5	6	7	8	9
Yes %	100%	95%	85%	36%	54%	41%	77%	96%	98%
Can't say %	0%	4%	7%	11%	7%	9%	20%	2%	2%
No %	0%	2%	7%	53%	39%	50%	4%	2%	0%

Fig. 6 Graphical representation of data

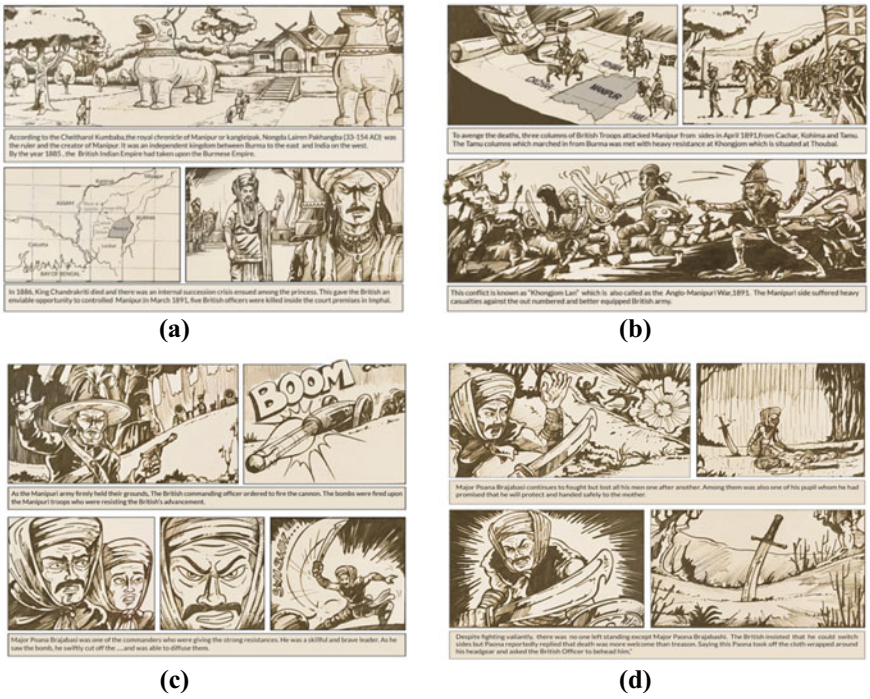


Fig. 7 Final visual narrative design output

survey and local people, experts, and interested party communicated through online platforms, mobile phone, etc. have supported and expressed their views.

6.5 Visual Narrative Design Output

Visual Narratives Design (VND) is an alternative way of visual storytelling where the historical information is designed along with a short description especially for the visitors. The development process is quite similar to the concept art development for making a film/series. But, the goal is a form of narrative illustration that can be exhibited either painted or printed, projected or, made a permanent relief sculpture at the Complex site for displaying information.

Traditionally, it is established that a narrative has two aspects- a story in a sequence of events and the expressions or shape-form through which the story is presented for communication [25]. So, visual communication is a very strong medium and has a long-lasting impression. People get cultured through stories which in turn becomes the protectors of the culture and the social customs of different ethnic groups [26]. Thomson in his study of the Four Story Forms: Drama, Film, Comic Strip, Narrative mentioned the comic strip as the most visual because of its illustrative presentation [27]. The VDN takes account of all the established concepts while coming up with the final design output.

The final VDN consists of four pages with the narrative detail. The first page consists of a single panel with narrative in the upper part and the follow up panel have two frames with a single narrative (Fig. 7a). The second (Fig. 7b) page has a panel with two frames along with a single narrative and a single panel with a narrative in the lower section.

The third page (Fig. 7c) has a panel with two frames and a single narrative on the upper part and a panel with three frames and a single narrative in the lower section. Page fourth (Fig. 7d) has a double frame with a single narrative for each of both.

The statements of the 17 individuals ($n = 17$) which includes historians, designers, educators, among others, who participated in the online virtual platform interview (Table 1) is listed below.

The overall statement shows that the VDN is a decent approach for effective communication and can help visitors know the actual happenings of the event which seems to fade away along with the modernization and other influences. It can be flexible and the mediums can vary depending upon the availability of resources.

The Khongjom Memorial War Complex being an important historical site need restoration in that information through any medium, so that the legacy is carried forward into the future meaningfully. The present development of the site has made the place more attractive resulting in the increase of visitors, which is a good thing, although the lack of in depth historical information was observed. The problem of the authentic sources remains in the new age where information is available at our fingertips and even real stories and events get fabricated with changing times. Hence, the traditional values and the cultural aspect of the heritage should be given due respect for the future.

The study has provided new insight by introducing the VND process which is effective, reliable, and has some significant quality in comparison to other form of communication as follows-

Table 1 Statements of viewer of the VND

Name	Designation	Comment
Mr. Chingtham Budha Singh	Retired, PWD, Govt. of Manipur	Very good part of our cultural and historical documentation
Mr. Geetchandra Rajkumar	Software Engineer, TCS, Brampton, Ontario	Informative, well designed and clearly narrates the historic events in a concise way. Great work and good luck
Dr. Khwairakpam Amitab	Faculty, NEHU, Shillong	A good approach to convey historical information and will aid in retention
Mr. Chingtham Babloo Singh	Branch Manager, SBI - Shillong	Gives a clear and quick historical background and is an innovative way of telling history
Mr. Kosygin Leishangthem	Faculty, MTU - Imphal	Impressive!! Children will love it in colour and bigger fonts almost double
Mr. Sarangthem Boby Singh	Lecturer, N.S.A, Imphal	Speechless and full of deep significance for the generations
Mrs. Sunita Thokchom	Bank Analyst, Scotia Bank, Canada	A great initiative and is very interesting to read. Well done and good luck
Mr. Ngangom Jitendra Singh	Teacher, B.H. School, Kangpokpi	The visuals and the narration are well timed and can easily understand
Mr. Surajkumar Meisnam	Business, Kwakeithel, Imphal	Clearly depicts the Khongjom Lan event
Mr. Yumnam Shyam Singh	3DArtist, Lamzing Technologies, Singjamei	Great in few visuals
Mr. Moirangthem Tondon Singh	School Teacher, Khongman, Imphal	Good idea we are proud of you
Mrs. Kamalabati Rk	Business, Chingmeirong, Imphal	Excellent!
Mr. Chingtham Pushpendra Kumar	ASI, Manipur Police Department	A brilliant idea. It will help visitors understand the significance of the site
Mr. Kh. Dinesh Singh	Proprietor & Artist, Bimola Art, Mumbai	These illustrations are easily understandable
Mrs. Naorem Yaipharenbi Chanu	Teacher, Shiv Nadar School, Noida-U.P	Very appealing and can help in wakefulness about the event
Mr. Rajkumar Chandrajit Singh	Business, The Library and Cultural Centre, Keibung	A new form of comic style with no dialogue but effective
Mr. Washington Meitei	Designer, NC Design and Services, Imphal West	People will appreciate the history through this art form

- Delivery of historical information in shortens forms with lasting impressions for the reader.
- No requirement of tools and technology or any other application.
- The learning process is made easier with intriguing visuals and relevant textual content.
- The alteration from the traditional comic book style or graphic novel.

There were difficulties faced in the study due to the pandemic situation resulting fewer visitors and also unable to meet maximum officials and volunteers.

7 Conclusion

The case study was carried out to find out whether the VND could be implemented as an effective medium and presents the event in a condensed form. The objectives of the study were to fulfil the need of conveying appropriate information through the design approach. Based on the results, it will be fair enough to say that the design can be utilized as an effective tool and will serve the purpose.

Shifting of technological tools in delivering the information might see another day in the future as well. The younger generation is mostly the one who will benefit from the VDN as they are prone to be misled by the change of design aesthetics and the changing environment of the heritage site. But ultimately, they are the one who will carry forward the legacy in time to come. Although, there will always be areas that will need further study and exploration for future scope. Application of modern technology might enhance the way of communication in the coming time as the evolution of the medium keeps on changing the traditional way. More study on the development might be required as this is just the base groundwork to fulfil the need of the hour.

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Consciousness in Yoga for the Transformation of Human Potentiality

Malay Sinha

Abstract Yoga is an art and science of consciousness. The Yoga Sutra of Patanjali defines yoga as, "stilling the mind and fluctuations of consciousness", the nature of consciousness which is personalized or adopted. It means observing and examining all our conscious mental activities, such as correct information, incorrect knowledge, memory, creative thinking, and sleep. Yoga promotes a broad and necessary method of consciousness, which tends to achieve full potential of mankind, union between individual consciousness and universal consciousness, and the Highest goal of life. i.e. Moksha (Liberation). In terms of human factors and ergonomics, all consciousness activities can be used to improve psychological and physiological principles. It is the practise of connecting with others, such as emotions of relatedness to other animals, the environment, and the cosmos, in order to reduce flaws, enhance productivity, and promote safety and ease. For the living being consciousness is perfectly essential for holistic development of an individual. Upanishads proclaims that the finite and infinite consciousness of living organisms coexists and can control arbitrary and involuntary functions. It is arguably one of the most important towering problem and its mysteries and functions which contain theoretical aspects that go beyond Western psychology to a greater extent. Scientists agree to accept the key role of holistic approach of yoga for promoting better physical, mental, emotional and spiritual health, and the best way to enhance human potentiality at a multidimensional level. This literary study is to explore the applied part of consciousness for transformation of human potentiality.

Keywords Potentiality · Moksha · Consciousness · Holistic · Cognition · Transformation

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1 Introduction

The word consciousness is derived from Latin word 'Conscire' meaning to know or awareness of something, it also denotes the state of being conscious or aware. Consciousness is seen only in living beings known as sentient and is totally absent in non-living or material things. This ability of knowledge or consciousness of itself and other objects in the world is ascribed to functioning of mind. Consciousness is perceived as an integral aspect of knowing as well as being, which involves in both science and spirituality. The Indian approach of consciousness is totally different. Adopting the subjective mode for investigating the nature of consciousness, consisting of introspection or looking within and analysis of the experiences of one's inner being, but in yoga found that consciousness is not the state of being conscious or self awareness, it is something more than this compare to limited perception of modern psychology. It is metaphysical entity, existing both within the experiments as well as outside in the world. The ancient yogic scriptures are replete with descriptions of the spiritual experiences of seer and sages, shedding light of the nature of consciousness [1]. In its objective aspect of consciousness is about something and refers to information one's knowledge or perception of events. But in its subjective aspect it is an experience of sensing something. The characteristic of consciousness is to pervade, and it is the principle of illumination, unseen. Perhaps it is like the unseen principle of electricity that is behind light. Consciousness remains an undivided principle of oneness, no matter how many forms it enters. Consciousness within is no different than the consciousness of the macrocosm. Consciousness within is like a magnet around which matter accumulates. All the dimensions of consciousness the experimental just as their supernatural, the individual as well as cosmic, the three states are waking, dreaming and deep sleep, the mind and its functions and transformations all these are concisely delineated in the texts of yoga philosophy. Patanjali defines yoga as, "stilling the mind and fluctuations of consciousness", the individualized or molded type of consciousness. This definition suggests an examination and perception of all our consciousness comparable to our psychological activities. Samkhya philosophy describes consciousness as two independent and eternal principles. These are consciousness (Purusha) and matter (Prakriti), usually called nature or matter. These two principles are described as being close to each other, even though they do not interact [2]. All stages of human growth, according to Swami Vivekananda, are manifestations of Brahman's intrinsic potential. Morality, power, education, employment, religion, and so on are all important aspects of human growth, and they are all manifestations of Atman-inner Brahman's strength [3].

1.1 Relation Between Consciousness, Mind, and Prana (Life Energy)

Chitta is a word used in yoga to describe total mental function. It comes from the root Chit, which meaning "to be aware." Feeling, thinking, and wanting are all characteristics of this chitta, which is the seat of awareness. Chitta is made up of an inner functioning instrument called Antakarana, which contains manas (mind), Buddhi (intelligence), chitta (memory) and ahamkara (I–consciousness, ego). According to Maharshi Patanjali our Mind continues to modify itself, called as Vritti (fluctuations of consciousness), the five vrittis are Pramana (right knowledge), Viparyaya (indiscrimination), Vikalpa (verbal illusion), Nidra (sleep) and Smriti (memory) [4]. Along these lines, chitta addresses to the absolute individual consciousness, which incorporates conscious, subconscious and unconscious state of mind and seems to be intelligent and conscious. But yoga says that it isn't. It has as it were borrowed intelligence. Chitta has a place to the domain of matter (subtle) and thus is idle. The Atman or Self is intelligence itself and is supreme consciousness. Prana, the cosmic energy, and awareness, the developing energy, are the two factors that make up each individual. Consciousness is static, while energy is dynamic, but it lacks intellect, knowledge, and consciousness. The development of prana transports consciousness throughout the human body and all other organisms. Prana is made up of both breath and consciousness. In reality, consciousness has the ability to observe everything, but it cannot move without the help of energy. These two forces are in charge of our bodies and minds, as well as our moods and emotions. The mind is an extension of a spiritual, transcendental consciousness that exists beyond the senses and beyond the grasp of the interacting mind. The mind, or interactive consciousness, directs our lives [5].

2 Rationale for Study

In yoga, study of human consciousness was enquiry into true nature of human personality which is nether the body nor the mind but pure self- consciousness. It is the Atman, the true Self, it gives us awareness 'I-exist'. This atman or individual soul is an inseparable part or reflections of an infinitude of consciousness called Brahman, which is eternal, unchanging, ultimate reality behind the universe. Although not knowing of man's true nature due to inherent ignorance man identifies himself body and mind and spend his time seeking external satisfactions. This state is described as bondage as well sufferings. Yoga's goal is to separate the everlasting nature of awareness from the external world's changing names, forms, and amounts. Living a conscious life means one has to actively evaluating his activities, decisions and options. Yoga practice provides tools and techniques how to develop the higher consciousness to transform human potentiality. It has the potential to bring about a profound shift in how we think, feel, and see life, as well as better physical and

mental well-being, but it goes beyond that. According to the Bhagavad Gita, the soul is a living thing capable of having experiences of reality around it, and the source is awareness. The ultimate goal of Yoga practice, according to Patanjali's Yoga Sutra, is Samadhi, a state of unified consciousness in which the mind's agitation is laid to rest and the mind begins to operate as a mirror, reflecting the truth of reality. The Upanisad proclaims that our original nature is peace, total bliss, knowledge, creativity, and freedom. Swami Vivekananda expressed this truth thus," Each soul is potentially divine. The goal of life is to manifest this divinity within by controlling nature, internal and external. These potentialities can emerge in each of us, allowing us to access our hidden realms. The Taittiriya Upanisad is based on five layers (koshas or sheaths) of consciousness and is regarded as a "very valuable springboard" for current scientific knowledge of cosmology and evolution [6]. Scientific research studies have found that Yoga practice promotes physical and mental health, through "the maximization of joy and the complete unfolding of the human potential" [7]. Yoga is the ideal lifestyle change because it attempts to bring the mind, body, and spirit together via Asana (postures), Pranayama (breathing), and meditation [8]. Undoubtedly, this study will provide deep insights into issues related to consciousness and deepen our understanding of the relationship mind, prana (vital energy), and senses that enhance human potential.

3 Literature Review

The aim of the present literary review was to critically evaluate the evidence for effectiveness of yoga philosophy and yoga practice in relation to consciousness as well as various human factors. Many of the research studies found as:

Yoga science also fully recognizes these factors because it looks at life as a whole. It emphasizes the organic unity of people and environment, discipline and happiness. It tries to restore the sense of balance and balance that thousands of small things in the environment are trying to disrupt or destroy [9]. In the later Upanishads and Yoga Samhitas period, people appropriately emphasized that the practice of yoga postures and yoga breathing can alleviate physical, mental, and moral obstacles (Yoga Chudamani Upnishad, Hath Pradipika and Yoga Vashistha) [7]. Hatha Yoga can assist manage physiological factors including blood pressure, breathing, and heart rate, as well as metabolic rate, to enhance total exercise capacity. To promote general well-being, this mind–body treatment incorporates physical postures, breathing exercises, and meditation [10]. Thoughts and experiences are integrated with physical and quantum levels of awareness in mind–body work. People experiment with diverse bodily sense modalities to create new consciousness. Chakras are utilised to develop consciousness on psychological and spiritual levels in yoga traditions. Chakras are subtle energy centres, not physical energy centres [11]. Intellect can be sharpened through meditation and breathing exercises. Increased capacity to focus, less mind wandering, enhanced arousal levels, more pleasant feelings, and lower emotional reactivity are just a few of the recognised cognitive advantages of breath-focused

meditation and yogic breathing techniques [12]. We can trace the roots of the quantum development of body, mind, and consciousness from the Big Bang to physics, chemistry, biology, and psychology in the deep psychobiology of psychotherapy, now dubbed neuropsychotherapy [13, 14]. As per Vedantic terminology, The living cell, on the other hand, reveals the properties of sat (existence) and cit (consciousness). In its basic experience, or knowledge, of its environment, the cell reveals the presence of consciousness. Since then, evolution has been a steady unfolding of consciousness with each step in the organism's development; and this development reaches a tipping point with the appearance of a on the evolutionary scene, when experience reveals a new dimension of awareness, namely, self-awareness alongside non-self awareness, a subject awareness alongside an object awareness. The subject, the self, cognition or knowledge advances from the basic to the secondary logical intellectual level at this stage, culminating in man's near-total comprehension and domination over the external world and a small knowledge of himself as the subject, the self [15]. General well-being may be characterised as a subjective sensation of contentment, happiness, satisfaction with one's life experience and position in the workplace, a sense of accomplishment, utility, belongingness, and a lack of anxiety, discontent, or concern, among other things. As a result, general well-being encompasses not just these aspects but also being physically, intellectually, emotionally, and spiritually healthy. Yogic techniques are capable of addressing all aspects of general well-being [16]. Certain yogic practises can help people manage their drug and alcohol addictions. Similarly, ego issues and emotional instability are to blame for violence, group disputes, and biases in society. And yogic training programme can improve performance in the areas of speed and accuracy [17, 18]. Higher functions of the central nervous system, such as perception and planning, execution, and learning and memory, are influenced by yoga activities. It causes the autonomic balance to shift in favour of the parasympathetic limb. Yoga improves cognition through enhancing perceptual awareness, suppressing unwanted stimuli, and reorienting confused perception. Yoga is both a way of life and a philosophy that explains how to create a balanced personality. Yoga's goal is to unite the mind and body so that they can work together in harmony. As a result, Yoga is a methodical method of developing momentum in order to reach a complete man [19].

These scientific studies confirmed that the inextricable connection of consciousness in yoga plays a vital role in the holistic development of the personality of an individual as well as their environment and lifestyle.

4 Methodology

Current literary research is based on qualitative, fundamental and conceptual research methods, which is descriptive and theoretical in nature. In this qualitative research of hermeneutics, the concept, theory and philosophical methods of hermeneutics based on meaning interpretation are used. Hermeneutics mainly focuses on the meaning of text or its analogs to enhance understanding. This explanation aims to reveal

its meaning or potential coherence through current knowledge, so that it can be relevant and insightful. The main purpose is to reveal all relevant concepts and aspects inherent in consciousness. This study is limited to textual and procured theoretical information through two main sources, the primary sources are various yogic texts such as Mandukya Unpanisad, Taittiriya Upanisad, Aitareya Upanisad, Brihadaranyaka Upanisad, Samkhya Philosophy, Bhagavad Gita and Patanjali Yoga Sutra etc. and the secondary source includes Books, Research papers, Conference papers, Articles, and Websites etc.

5 Objectives

- To gain familiarity with functions of consciousness phenomena which interplay between mind and consciousness and senses.
- To analyze role of consciousness in relation to transform human potentialities
- To understand how the yoga philosophy illumines the ultimate mysteries of the Divine Consciousness (Brahman).
- To establish that the yogic texts are truest essence of consciousness, a practical manual to conscious Evolution.

6 Concept of Consciousness in Yogic Texts

The four states of consciousness, according to Mandukya Upanisad, are awaking (jagrata), dreaming (swapna), deep sleep (Susupti), and turiya (pure Consciousness). They are called four quarters or parts of Brahman or cosmic reality. The **first** quarter of consciousness is known as Vaisvanara (waking), the sphere of activity in the waking state is the external, conscious world objects. The **second** quarter of consciousness is **Taijasa** (dreaming), the sphere of activity in the dream state is the internal, conscious of internal objects. The **third** quarter of consciousness is named as **Prajna** (deep sleep) In that sleep state, not for anything desirable does one have any desire; Not the slightest trace of dream does it see in that state of deep sleep. In the sphere of deep sleep, there is just one "homogenous mass of consciousness" alone; It is full of Bliss; in it, Bliss is all there is to be enjoyed; It is, as it were, the very bottle-neck of Potential. Such is the third quarter called Prajna. The **fourth** quarter of consciousness is called as **Turiya** (Pure Consciousness)—"Not conscious of the internal world; nor conscious of the external world; not conscious of the both worlds; nor just mass of consciousness; not conscious (aware of anything at once); nor unconsciousness (not aware of anything); beyond perception, the unseen; beyond empirical transactions; beyond the grasp of the sense organs; beyond inference, indefinable incomprehensible; beyond thoughts, ideas, or concepts; beyond description; proved by the sole belief in One self of all three states". (Verse 7) Thus, the Pure Consciousness (Brahmic) state has been described as the fourth state, above

the waking, dream and deep sleep states [20]. Panchakosha was explained in terms of fivefold consciousness in the Bhriguvalli of **Taittiriya Upanisad**. Pancha refers to five, Kosa means sheaths, while maya means illusion. Each kosha function at different layers of consciousness, and they interact and overlap with each other, ranging from gross to transcendental dimensions such as bliss, no duality. Brahman etc. The five kosas are 1. **Annamaya Kosa**, the sheath made up of physical body. 'Anna' refers to food that nourishes the physical body. It is described as, he, that man, is unquestionably a product of food's essence. This is his head, his right arm is his right wing, his left arm is his left wing, his trunk is his torso, and his tail is this support below the navel. The Upanishad compares the human body to that of a bird in this passage. Like a bird, the entire body is balanced. This kosa for experience of consciousness of Self and connect ourselves to the outer world; 2. **Pranamaya Kosa**–(Vital sheath) As previously said, there is another inner self made of vital air in comparison to this self formed of the essence of food. This one is filled by that (vital breath). That (self) which is this is, without a doubt, a human shape. Its human shape is modelled by that of that (earlier one i.e. food). Prana is its head, vyana is its right wing, apana is its left wing, akasa is its trunk, and the ground is its tail and support. Prana is a term that refers to life force and is a component of cosmic life. It's the power of consciousness that exists inside us and all around us. 3. **Manomaya Kosa**-(mind sheath) in comparison to this vital body, the mind creates a separate interior self. This has been filled up by that one. This self is likewise shaped like a human being. This mental body's human shape is similar to the vital body's human shape. The Yajur-Veda is the head, the Rig-Veda is the right wing, the Sama—Veda is the left wing, the teaching is the trunk, and the hymns of Atharva and Angiras are the tail, the support of that (Manomaya Kosa). It is a subtler aware energy that exists inside the physical body but is more mental in character. The term 'mano' refers to the mind, but it also encompasses ideas, emotions, the senses, and the subconscious; 4. **Vijnamaya Kosa**-the sheath of wisdom, which refers to knowledge. awareness and inner perception. There is another internal self made up of valid information that exists alongside this mental sheath (Manomaya kosa). This has been filled up by that one. This one, as previously said, has a human-like appearance. It is formed like a human in the same way that the last one was. Faith is the head, right is the right wing, truth is the left wing, absorption is the trunk, and Mahat is the tail, the support. Our thinking is governed by the buddhi (intellect), which also regulates the Ahamhara (I awareness) and makes decisions. The consciousness psyche, the individual mind, and the global mind are all connected by this kosa. The mind receives universal consciousness through this kosa; and 5. **Anandamaya Kosa**-(sheath of bliss) in contrast to this (Vijnanamaya) cognitive body, Bliss has created another inward self. By the time that one was finished, this one was completely full. This one, as previously said, has a human-like appearance. It is formed like a human in the same way that the last one was. Its head is joy, its right wing is happiness, its left wing is tremendous delight, and its trunk is bliss. Its tail, its support, is Brahman." Ananda is the condition of consciousness that exists beyond of all attachments and desires. It is possible to transcend from the lower to the higher self. It turns a source of our unconditional love, eternal happiness and harmony. The condition of liberated

mind, where one can understand what his "Real Identity" is [21]. **Aitareya Upanisad** expresses the consciousness as the knowledge and it is Brahman itself in this verse as: "…All these have Consciousness as the giver of their reality; all these are impelled by Consciousness; the universe has Consciousness as its eye and Consciousness is its end. Consciousness is Brahman" (Aitareya Upanishad 3.3). Here the Prajna is the basic consciousness with an entity of it being an entity; the awareness is foremost, first of the knowing. Brahman is positioned in Prajna. It states that everything is generated by consciousness [21]. In **Brihadaranyaka Upanisad**, Yajnavalkya states that the Universe, Reality and Consciousness is infinite in this verse as follows: Om, This (world) is endless, and that (Brahman) is infinite. The infinite (Then) proceeds from the infinite (Then), accepting the infinite (universe's) infinitude, and remaining as the infinite (Brahman) alone. (B U-5.1.1). Thus, the 'Infinite,' is meant by the word 'That,' is Brahman. At that point knowing itself as the incomparable, infinite Brahman, in order to feel, 'I'm that infinite [21]. The Bhagavad Gita pointed out that Atman or soul is the source of consciousness, and consciousness is a living organism that can experience the surrounding reality. The presence of the soul is known by its symptom called consciousness. Krishna says: "Oh! son of Bharata, as the sun alone illuminates all this universe, so does the living entity, one within the body, illuminate the entire body by consciousness." (B'Gita-13–34) In this way, consciousness is a deductive proof or indication of the existence of Atman or living organisms. Atma is the seat or origin of consciousness [22]. **Samkhya philosophy** advocates that the universe is composed of two separate realities: puruṣa ("pure consciousness") and prakṛti ("matter"). These two realities exist in parallel and do not affect each other. Puruṣa is simply the transcendent self or pure consciousness. It is independent, absolute, free, vague, mysterious by different establishments, past any idea or tactile experience, past any language or understanding. It is still pure, "non-attribute consciousness". Prakriti is the principal cause that shows the material universe-everything with the exception of puruṣa. Prakriti clarifies any matter, including thought and matter and energy or power. Since it is the primary guideline of the universe (tattva), it is called pradhāna, but since it is an oblivious and unintelligent standard, it is additionally called jada. It is comprised of three key characteristics (trigunas). Sattva is made out of balance, fineness, gentility, brightening, and euphoria; Rajas is made out of dynamism, action, excitation, and agony; and Tamas is made out of idleness, coarseness, substantialness, blockage, and sloth. All physical occurrences are seen to be expressions of prakti, or primordial nature's development (from which all physical bodies are derived). The 23 components of the unconscious primordial materialism, prakriti, include intellect (buddhi, mahat), ego (ahamkara), and mind (manas); the intellect, mind, and ego are all considered types of unconscious matter [23]. Therefore, thought processes and mental occurrences are only conscious to the extent that Purusha illuminates them. **Patanjali** outlines five modes of consciousness (vrittis) occurs in the mind of all human in his Yoga Sutra (Chap. I-6) They are 1. **Pramana**: (Valid knowledge) is related the facts include all the experiences of the mind and sense objects that are in direct or indirect contact with the objects at that time and the spiritual perception corresponds to the objects. Different types of right knowledge are reflected when consciousness

is in a condition that accurately reflects proper information of external reality - direct knowledge using our five senses, indirect knowledge using our five senses, (knowledge is directly acquired through the environment) and so on. The inference is our awareness of applying logic and reasoning to figures and inferences, and competent evidence is proof that we may trust others' expertise and experience; 2. **Viparyaya**: (wrong knowledge) is a type of erroneous knowledge that has no basis in reality. This consciousness is likewise dependent on some type of external object interaction, but the mental representation does not match the thing. Treating anything as a non-thing, a condition that can be removed by awareness, is what consciousness source is characterised as; 3. **Vikalpa**(imagination) is the mode of consciousness is not a result of correct knowledge or Inference and having no (comparing) reality. This state of consciousness is not the product of accurate information or deduction. It is solely powered by words and is devoid of any physical objects. Although the use of awareness has nothing to do with the physical reality of any activity, it may be comprehended in everyday terms; 4. **Nidra**- (Sleep) is a consciousness there is no content in the mind is classified as consciousness. During the time that a person is in his state, his thoughts are like a blank or a blank. Consciousness is defined as the absence of content in the mind. And there's a solid explanation for it. A person's thoughts are like a blank or a blank throughout the time he or she is in this state. In the world of consciousness, there is no Pratyaya. This is a state of awareness that is predicated on the absence of anything. a state of consciousness that occurs during deep sleep and is recalled when you wake up; and 5. **Smriti** (Memory) is referred that when perceived subjects do not fade away (and return to awareness through impressions). All five states of consciousness contribute to memories. This is the connection between consciously perceived pictures of sentient objects that may cause pleasure or suffering. Each state of awareness leaves an impression (samskara) in the mind's storehouse, which manifests as a mental memory [24].

7 Transformation of Human Potentiality According to Yogic Texts

Different yogic texts explicitly on consciousness stresses for developing human potentiality in order to grow and rise in consciousness and in understanding of our true nature. The various disciplines for consciously transforming consciousness as follows:

The **Mandukya Upanisad** considered and taught the sacred syllable Om to be the force behind states of consciousness. Either reciting or thinking Om is narratively answered to cause a calm mental state. Om is the primal sound that gives rise to all other sounds and creation. Om, which is made up of the letters A, U, and M, is a chant that encompasses the entire articulation process. It sounds like a gong that gradually fades to a point and then merges into silence. When one achieves Om, he or she unites with the Absolute. AUM also has four parts, it consists of three letters

and silence (AUM + Silence) at the end. In terms of our waking, dreaming, and dreamless sleep, the first three are A, U, and M, which correlate to the first three quarter of Atman or Brahman. The fourth quarter is AUM's Silent phase, which doesn't have a letter. This state of silence corresponds to the Turiya state of Atman. Through practice of meditation on AUM and self reflection one can experience higher state of consciousness or Brahman both in its cosmic and in it's a cosmic aspect. One, who meditates thus, has the capacity to measure all things, that is, to know everything – he becomes '**Sarvajna'**. He becomes the measure of all things; he becomes the yardstick for the consciousness of everything in creation [25]. **Taittiriya Upanishad** describes the human body encompassing five bodies of consciousness, the experiential sources of creativity. Yoga techniques for handling and developing various layers of consciousness as: **Annamaya Kosa**,(physical body) is direct experience of consciousness of being alive, practicing Asana,(yoga posture) Kriyas(yogic cleansing practices) and diet,(vegetarian, Sattvic in nature), one can awaken and expand inner consciousness of inner world and also purified the gross body as well as total personality; **Pranamaya kosa**, (vital body) is the consciousness of one's existence. It can be handled and purified through the practice of Pranayama, which enhance of consciousness travel from gross, to subtle and causal bodies. Regular practice of yogic breathing, Kapalabhati, Bastrika, Sheetali, and Nadi Shodhanaetc. one can become aware of awareness itself and blissful state. **Manamaya Kosa**, (mind body) is consciousness of our thoughts, feelings, mind and emotion. It functions on three levels as Conscious Subconscious, and Unconscious. Yoga practices which enhancing this Kosa includes pranayama, Meditation, Karma yoga, Bhakti Yoga, Prayer, Study of scriptures, pratyahara, Yama and Niyamas (the yogic moral ethics towards the society and self-discipline) are very efficient; **Vijnanamaya Kosa**, (intellect body) is subtle knowledge consciousness through which one can reach intuitive knowing and higher levels of consciousness. Practices for enhancing higher level of consciousness such as dharana, (mental focus on an object) and dhyana, (regular meditation practice,) Karma Yoga, Self introspection, Jnana Yoga etc. are progressively help us to channel our focus towards establishment of 'higher' consciousness. This Consciousness mind turns within towards the soul for seeking the True self; and **Anandamaya Kosa**, (bliss body) is Pure consciousness, the spiritual or causal body, where, finally, you become one with the "Divine Spark", which is our Atman. To develop and purify this kosa, yoga practices like karma Yoga, happiness analysis are efficient to experience higher level of consciousness. It is said that when you realize the Self or God, you reach "Mukti," or liberation. As long as the human beings are to be found in the lower four stages of consciousness- Annamaya, Pranamaya, Manomaya, and Vijnanamaya—they are considered to be in the life of material consciousness, but as soon as one reaches the stage of Anandamaya, i.e. bliss, he is a liberated soul. In **Brihadaranyaka Upanishad**, Yajnavalka instructs Maitreyi to follow these exact steps to realize Brahman or Absolute consciousness. The Self is deserving of realisation, or should be made so. It should be first heard through a teacher and the scriptures, then pondered via logic, and last persistently focused on.' By combining these three, then only true realisation of the unity of Brahman is accomplished, not otherwise—by hearing alone. Here the long established steps of

Jnana Yoga (path of knowledge) which provides many accessible channels to direct our consciousness to enhance human potentiality and also techniques for attaining an experienced-based transformation of consciousness. The Bhagavad Gita, on the other hand, urges us to actively cultivate the "Yoga" mindset in order to turn our servitude into mastery. It describes "Yoga" as mental balance (samattva) in the face of success and failure, desired and undesirable consequences (Chap. II-48). Due to the inextricable connection between human and environment, one can inculcate self-discipline and a greater awareness of the world and ourselves in order to discipline our senses, mind, emotion, and intelligence. And it adds that being seated in this yoga-attitude, or samatva-attitude, is the secret to perfection in all of our acts (Chap. II.50) [22]. **Samkhya Philosophy** provides an experiential path of transformation, a practical, logical method finally it returns us back to our original face –pure beingness or the 'I' that is consciousness itself. Samkhya is the system that explains, step by step, how the universe is created – not only 'in the beginning', but through every moment of our lives and known or unknown to promote transformation of consciousness. Samkhya is that the whole creation is a manifestation of conscious intelligence and observed that "everything is consciousness". All things arise from Purusha i.e. pure consciousness, source of all the manifestation everything can be said to be consciousness. Samkhya philosophy very veil states that when the worldly influences are brought to an end through correct knowledge, the soul abides in itself in its purity. The core of the **Patanjali Yoga** practice primarily based on consciousness, once the mind is controlled and fluctuations of consciousness stilled, then one gets established in his own true nature. To realize our true nature Patanjali has given eight limbs of yoga for attaining holistic personality, such as a person's physical, intellectual, emotional, social and spiritual development. Practical methods for awakening and expanding direct experience of higher faculties of consciousness, intellect and quality of consciousness and potential self transformation. The eight limbs of yoga are - Y**amas** (inner purification of consciousness), **Niyamas** (outer purification action through consciousness), **Asana** (posture for consciousness of body), **Prāṇāyāma**, (consciously breath control), **Pratyahāra** (disengagement of the senses), **Dharaṇā**, (concentration-inner consciousness), **Dhyāna**,(meditation), and **Samādhi** (absorption/identification with purusha) [24].

8 Summary

Yoga takes us back to our real nature consciousness from sensorial and material world; one can find peace and stillness within. Methods of yoga focused on personalizing the conscious movements such as ascending, growing, actualizing and expanding of consciousness. It also provide support for transformation at physical, mental, social and spiritual level necessary for theological corrections and uncover our limitless potentialities, that we could fly ever higher, ever faster. According to Shri Aurobindo:

"Yoga is a methodological effort towards self-perfection by the development of potentialities latent in the individuals. It is the process by which the limitations and

imperfections can be washed away resulting in a superhuman race." [26] The ordinary perception of consciousness is limited to three includes conscious, subconscious and unconscious, but in yoga something beyond ordinary consciousness is Turiya i.e. pure bliss, non-duality, Brahman etc. All human are capable to enhance the highest state of their potentiality and well being, by expanding of transcendent state Ananda (bliss), not an ordinary well feeling it is thoughtless state. Through different kinds of yogic practices like meditation, Pranayama, Pratyahara, Samadhi, prayer etc., one can alter consciousness as well as divinity and enhance freedom, creativity, bliss and knowledge.

9 Conclusion

The prime goal of yoga is to understand the real nature of our consciousness. Yoga philosophy provides method and techniques to actualize a conscious relationship with the vast cosmic forces that lie beyond socially conditioned consciousness or awareness. By transforming consciousness one can achieves radical changes in perception, thinking, understanding and interpretation of the world. The different texts and scriptures of yoga philosophy focuses on the holistic development of self and consciousness and offers help for transformation at physical, mental, intellectual, social and spiritual level utilizing the psychological and practical steps. Thus, it can be reasoned that yoga as a mindfulness practice and the true importance of yoga is union. It is simply the way disclosure and the guide for accomplishing association with everything. Technically, however yoga is defined as equanimity in dualities of life, in Bhagawad-Gita, it is never intended to be perceived as a method to accomplish some temporary gain, with accomplishment inspiration. Neither Bhagawad-Gita nor Upanisads are in limited perspective in this way. Both views Yoga as a method of living that ultimately lead to supernatural Self- realization, as a result the transformation of the entire human system achieved holistically.

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Empathy, Vulnerability and Learning Theories in Higher Education

Vikram Mathur and Anirban Chowdhury

Abstract A number of students arrive at the University after much struggle and anxiety during their final years at school. For some, circumstances and opportunities have provided for tumultuous experiences causing the mental disbalance among such students. This paper aims to identify the instructional environments that are vulnerably not empathetic for students in higher education and to strategise a theoretical framework to strengthen the empathetic values in the learning environment for helping learners in higher education. Referencing the various theories of pedagogy and Instructional Design, the ideal set of values for learning will be established. Taking into account the aspirational and emotional quotient of the present day learner, various psychological support techniques will be identified and tested for their viability in the higher education learning environment. Analyzing the impact of various pedagogical styles, emotional quotient and aspirations of the learner in higher education and envisaging the challenges of the modern day teacher develop a strategy to prepare the theoretical framework for an empathetic learning environment. This paper identifies the structure for a learning environment in higher education, based on empathy and respect, leading to an ever resonating and congenial teacher – learner relationship.

Keywords Emotional · Empathy · Gen Z · Higher education · Instructional design · Vulnerable learners

1 Introduction

Today, we have an education system which is burdened with the responsibility of preparing students to face all and any eventualities that may show. Dealing with this burden causes stress and anxiety that is automatically passed on to the consumers of education namely the teacher and the learner. Teachers are constantly trying to complete the vast syllabus and learners struggle to cope up with their learning. Such

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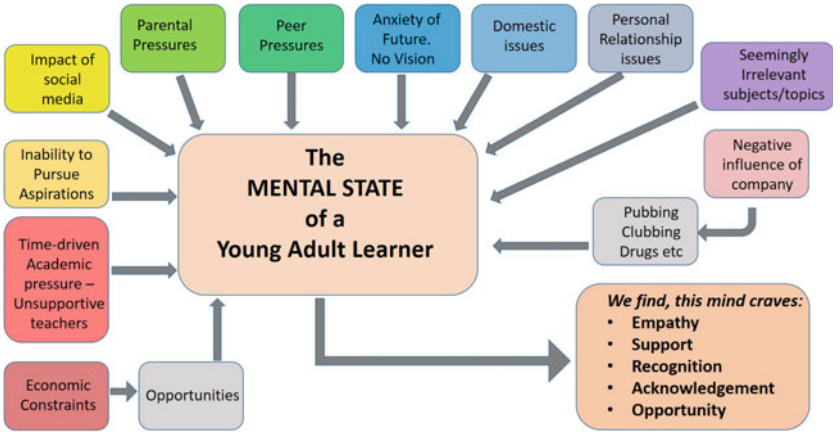

Fig. 1. Factors influencing the mental state of a young adult learner.

circumstances have resulted in generation of quick fix methods. The overworked Teachers are barely able to deliver the subject instruction let alone ensure student learning outcomes. Students who are left to themselves to cope with huge content and clear exams to get certification, use the technique of shallow learning. Deep learning as a concept has almost become an unachievable goal for most.

Through the schooling years, in order to cope, students develop the skill to memorize the content to enable answering questions in the exams. Once the exams are dealt with, the mind purges the matter that was hurriedly crammed in, to make room for further such actions. Most students complete school with little recollection of what they studied. Times have become so competitive that the mental state of the Young Adult Learner who is finishing school and entering the phase of Higher Education is so pressurized that it begins to crave for empathy, support, recognition and acknowledgement to help face the challenges of life (Fig. 1). Such students face difficulties when they arrive to receive their higher education.

2 Theories in Instructional Design

Meanwhile, academicians and researchers have been working with data, findings and experiences to devise methods to suitably overcome the issues faced by the learners and their teachers in the current education system. Concentrating on Instructional Design, three categories of theories have emerged–Behaviorism, Cognitivism and Constructivism. These theories delve on the need to prepare a strong educational structure that may systematically facilitate sustainable learning.

The Behaviorism theory is based on observable behavioral changes. It focusses on creating a system of repeating desirable behavioral patterns till they become habits (as in automatic) [1]. Whilst experimenting with behavioral patterns in animals, it

was seen that when food was provided to a dog after ringing a bell on successive days, the dog developed a conditional response of salivating each time the bell rang. This behavior developed to a point that each time the bell was rung, the dog salivated irrespective of whether the food was provided or not. The theory examines how student behavioral patterns can be conditioned similarly to respond to academics and its processes. Testing the theory, it was felt that an instruction may evoke a good learning outcome but the individual performance of learners may not be enhanced. But then, it was realized that learning takes place when the bonds are formed into patterns of behavior [1, 2]. Another issue is that the current student remains too distracted to get involved with their learning process. Building into the stimulus, the art of finding relevance sensitively [3] draws the student attention quite effectively. In response to this theory there is apprehension that creating behavioral patterns may be inhibiting for creativity. Well, maintaining a conceptually oriented approach to allow for free application of thought will work seamlessly in such cases [4]. Though this process needs time and continuation to bring about behavioral changes, using the Skinners Operants' conditioning mechanism for behavioral shaping [1] could help bring in quicker success.

The theory of Cognitivism examines behavior, to establish the thought process behind it. Observing the changes in behavior, one can make sense of what's happening in the mind of the learner by using them as indicators [1], basically, identifying the individual needs of different learners or their emotional requirements [5]. The mind thus develops structures of knowledge through its learning and understanding experiences [6] which in turn explain the interpretations of the mind. To address the issue of Unobservant and preoccupied mental state of the learner, this theory suggests aligning the cognitive behavior of the learner with the curriculum, using relevance of learning [7]. Often, the lack of interest in exploring subjects is overcome by Inclusion of exploratory exercises that offer challenge [8]. Establishing the connection with the social context in which the learning needs to happen takes care of that potential challenge [9]. Sometimes lack of communication and understanding between the teacher and the learners causes gaps in the relationship resulting in poor engagement and performance of students [10]. A Teacher needs to build the bridges of communication from the student's end so that his instruction begins from where the student is located (in his understanding) and definitely not from where the teacher would have liked to begin his instruction [10].

Indifference of the system to learners with special needs creates a serious impediment in their cognitive learning process. These learners may be categorized under various heads. Students with ADHD (Attention Deficit Hyperactive Disorder), have social and emotional issues, and limited educational outcomes [11, 12]. These students cannot follow instructions, nor finish tasks on time. They interrupt people, cannot sit still or just stand up with no real purpose. They have problems interacting quietly, are generally messy, prone to easily distracting themselves, constantly interrupting the teacher/other students and moving from chair to chair. They do not finish tasks on time, talk aloud, do not focus on teacher instructions, occasional attention-getting behavior and sometimes showing a small degree of fidgeting [11, 13]. Special provisioning for such students would include: seat closer to the teacher,

extra books for home, repeat directions, incorporating visuals, short quiz, outlines of notes/lesson, color coded assignments, break down Tasks/work, detailed rubrics, directions are written/spoken, limit room distraction, organizing notebooks, teaching using 'concrete' methods before abstract, create a behavioral plan, Poster projects - more student centered, minimize length of Qs., Use sticky notes [14]. Then there are learners who may have sight impairment, hearing or speech impairment issues. For the visually impaired Braille books and more articulation in verbal instruction would help bridge the learning gap substantially. For the hearing and speech impaired students, instruction to be more graphic and illustrative. Encouraging students to communicate using hand gestures, drawing and other visual methods. Similarly learners with physical disabilities need considerations like simplification of assessment methodology and creating requisite infrastructure that would provide for a supportive learning environment.

The Constructivism Theory believes that depending on our individual experiences and schema, we construct our own perspective of the world [1]. The Constructivism approach basically prepares the learner to problem solve notwithstanding ambiguous situations i.e. relating one step to the next [15]. To tide over remembering after understanding issues, constructivism suggests learners use flow charts, metaphors and analogy making [16]. This theory recommends sensitizing students to the fundamentals [17] and building the bridges of correlations and relevancies by aligning the Teacher, curriculum and social construct. From the students' perspectives, engaging teachers were those who communicated, cared, and enthusiastically presented active learning opportunities [10]. Not being able to apply knowledge and skill in new situations or even form abstractions, is quite normal in the initial stages of contextualized learning for any learner [18]. Thus, frustration and confusion during these stages is quite expected [19]. They should be allowed to develop and build their own understanding and the teacher, work with them to develop their higher cognitive skills [20]. Even though the joy of learning through discovery may excite the learner, the old habit of simply aping the better students may keep them from building on their own knowledge structures or construct meaning [18]. Collaborative ways of teaching encourage discussions, clarifications and evaluation of others' ideas [21]. New curricula should focus on problem solving models and be intricately designed to respect, factor-in and make good the gaps that may occur between the previous and the new learning experiences of the learner. [22]. Constructivists believe that assessments should only be used as an important tool to ascertain the learner's progress for the teacher, and for the student, a method of enhancing his/her learning. It may cause stress and demotivate learners if used as an accountability tool. [23]. The philosophy of building the learner's reasoning, finding meaning and understanding should be done through facilitating and interacting proactively on the teacher's part [20].

Our individual schema and experiences help us create our own perspective of the world, is the primary basis of the Constructivism Theory. No matter how ambiguous the situation, it prepares the learner to problem solve. The theory got further divided into two categories - Cognitive Constructivism and Social Constructivism. The former talks about how an individual interprets objects and events to construct his/her knowledge based on beliefs, mental structures and experiences from the past, thus

creating their own reality [1]. Whereas Social constructivism, talks about collaborative work, peer learning, learning from each other. Discussion with others always helps in thinking through ideas, exchanging views, perspectives and how others describe things. Indulgence in such social experiences will provide for strengthening our logical conclusions [24]. Discussing ideas promotes 'socially construct' knowledge and almost always results in shared agreements and a better understanding of the facts [25]. Interpretations of societal conditions by the older generations often push and encourage the younger generations into the competitive mode wherein sharing is considered detrimental to the building of the self. Being introverted and selfish on achievements is considered beneficial by this older generation due to their own insecurities, which they inadvertently pass on to subsequent generations [26]. Miro a virtual tool, allows people to collaborate virtually on a platform [27]. Cognitive Constructivism is better understood when divided into two components - Realistic constructivism and Radical constructivism. Realistic constructivism says that cognition involves the process of learners using external structures located in the environment to construct their own personal mental structures. Whereas, Radical constructivism is about cognition servicing the organizing of the experiential world of the learner, rather than to discover ontological reality [1]. Often misinterpretation of certain truths and inclusion of these into the mental structures result in derailment of the thought building process. According to the Realistic Constructivism theory, elaborate teacher-learner discussion and debate on fundamental concepts after ascertaining the level of previous understanding of the learner can prevent the misinterpretations [28].

According to an article in the American Educator, the achievement gap between students of color-white students and high- low income groups tend to widen with the constructivist teaching methods, when observed from the Radical constructivism standpoint [29, 30].

3 Challenges Faced by Design Learners at Various Stages of Design Education

A Learning Experience Journey Map (Fig. 2) has thus been created as the framework to facilitate effective design learning in higher education. The framework comprises six phases in which the teaching will happen to ensure the learning. Phase 1 is called the 'Orientation Program'. The common issues noticed are that no proper guidance as to program selection is provided and learner aspirations and identity issues get mostly ignored. This phase deals with providing guidance for Design program selection based on the aspirant's vision and the exact learnings required to achieve the vision through experiential and exploratory methods. Phase 2 is called 'Foundation Program'. This phase deals with negating the prevailing unaccommodating practices, indifferent attitudes and time/syllabus driven teaching methods. Being the

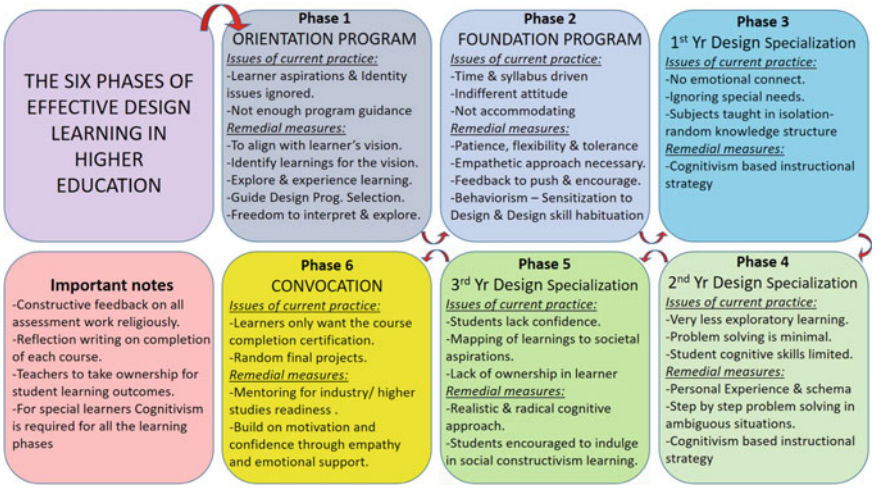

Fig. 2. Learning experience journey map.

formative stage for learning to begin, it shall promote patience, tolerance, flexibility, empathetic approach and behaviorism. It will facilitate regular feedback to the learner to provide for encouragement and push for higher results. Phase 3, '1st Year Design Specialization' is essentially implementing Cognitivism based instructional strategies. Having gone through Behaviorism instructional strategies in Phase 2, the students now need to interpret and internalize the thought behind their behaviorism and actions. Phase 4, called '2nd Year Design Specialization' builds on personal experience and schema. It encourages step by step problem solving in ambiguous situations using an instructional strategy based on the Cognitivism theory. Phase 5 or '3rd Year Design Specialization' deals with confidence building, ownership taking and practicing all the variants of constructivism theory. This phase helps build the structures of knowledge and skills for the students, based on their realistic and radical cognitive experiences as well as the social constructivism learnings. Phase 6, the last phase is called 'Convocation'. In this final phase, students are guided to select appropriate topics to showcase their acumen most accurately. Mentors consistently provide for motivation and confidence through empathy and emotional support. Students receive full support and mentoring to help render them fully industry ready in all respects.

4 Problem Solving with Instructional Design

We use printed/online maps to provide geographical location, projection maps to discuss organizational growth strategies, fitness/training schedules for athletes etc. Essentially, though we know where we are going to start and where we wish to finish,

we need to prepare the road map for our journey to arrive at the decided finish. Logically approaching the matter we find that we need to accurately prepare this journey map on four counts. These four counts would be understanding current situation, final goal expectations, preferred method/technique and execution strategy. In education, Learner Maps help to chart out the teaching/learning strategies for various courses. In this case the four counts are named Learner characteristics (understanding the current situation), Learning Goals and Experiential Expectations of the Learners (final goal expectations), Teaching/Mentoring Pedagogy (preferred method/technique) and Instruction Presentation Medium (execution strategy). Learners Maps for courses in Design education can be seen in Fig. 3 (Learner's Map for Theory Course) and Fig. 4 (Learner's Map for Design Studio Course). A Learner Map has proved to be a wonderful tool to solve problems encountered in Instructional Design.

In most classrooms, the learner thinks the teacher will teach and learning will happen. Meanwhile, the teacher is thinking the learner will learn, as he (the teacher) is teaching. Either of the two assumptions don't work. The instruction needs to begin from where the student is located in his understanding and not where the teacher would like to begin his instruction. Some learners need help to develop recollection abilities for their learnings. Only when the student feels confident & ready to apply his learning to solve problems is the teacher's job successfully done. An instruction may evoke a good learning outcome but offering the relevance of the same, citing examples to illustrate application is key to true learning. Young adult learners who remain distracted, feel most comfortable with 'friends' who listen and align well with their aspirations. Teachers who are empathetic will find a responsive and receptive attitudes in their learners as they get included into the 'respected friends' category.

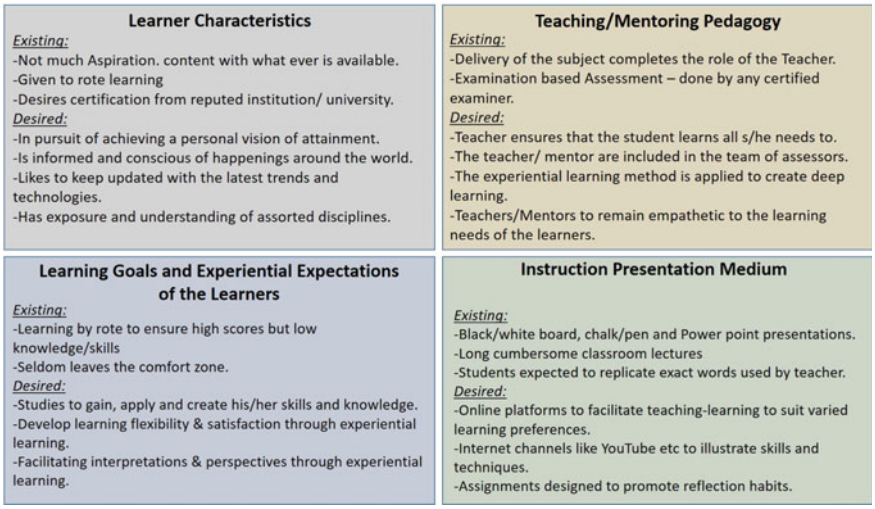

Fig. 3. Learner's map for theory course (Name of course: material technologies II).

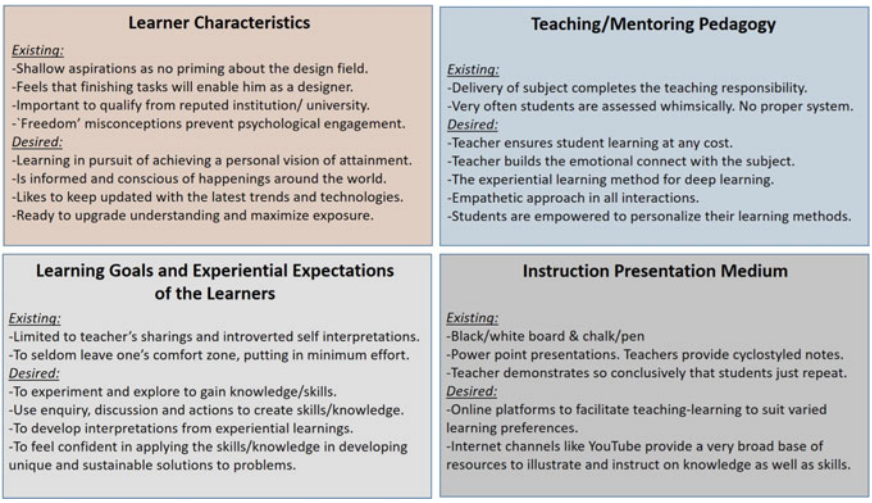

Fig. 4. Learner's map for design studio course (Name of course: domestic interiors).

Specifically in design courses, students need to be guided sensitively and systematically, demolishing the preconceived notions (due to over-exposure to set patterns) and mental blocks, making way for unconstrained futuristic thinking. Offering reinforcement (increase behavior) of desirable traits & punishment (decrease behavior) of undesirable traits, healthy learning habits can be formed through behavioral control. Repetition of this process will slowly habituate the learner to follow good academic behavioral patterns (Skinners Operants' conditioning mechanism). Students who doubt their self-capabilities need help in developing self-confidence and overcoming their insecurities and short-comings. Encouraging them to speak-up, opinionate and offer supportive arguments for their thoughts, provides for confidence building. New Topics/subjects that are considered invincible monsters should be introduced in their friendliest and simplest forms. Encourage and facilitate building informal relationships between the learner and the subject matter by identifying for the learner, his location (of understanding), and help in establishing the bridges of understanding. Learners normally study subjects to pass exams and carry no recollection afterwards to allow for fruitful application. Providing strong references to events and processes from everyday occurrences in the lives of the learners, helps in developing interest in a subject. This motivation leads the learner to begin his own exploratory journey. Inclusion of exploratory exercises that offer challenge would supplement this experience. For effective learning to happen, issues such as lack of social context need to be managed using Social Constructivism. As design essentially services society, the learning will never yield positive results if the learner is unable to connect his learnings with the social context. Using flow charts, metaphors and analogy in the teaching learning process will bring better design learning results. To prevent constructivism or any other reform movement from failing, it is important to build the bridges of correlation and relevance by aligning the Teacher, the curriculum and the social construct.

Contextualizing of learnings into abstractions and then converting into knowledge and skills, is extremely important in constructing their own understanding or it will lead to confusion and frustration in learners. It therefore becomes necessary that the teacher contributes toward the healthy development of higher cognitive skills of his learner. If the assessment of the learner's learnings focuses on the factors of evaluation and synthesis of his/her reasoning, they will each actively construct meaning and build an appropriate knowledge structure for themselves. Instructors of design subjects need to emphasize on problem solving models and find all means to fill up the gaps between the learner's learning experiences of the past and the present. Based on meaningful interaction and facilitation, the learners should be encouraged to construct their own individual meaning and understanding.

5 Conclusion

The mental state of a young adult learner in present times is heavily burdened with external factors, preventing stable and sustainable growth for the future. These external factors include economic constraints (thus missing opportunities), inability to pursue aspirations, the impact of social media, parental and peer pressures, anxiety about the future (lack of vision), domestic issues, personal relationships, studying irrelevant subjects, negative influences of company (pubbing, clubbing etc.), and dealing with academic pressures coupled with unsupportive teachers. These young people have come to crave empathy, support, recognition, acknowledgement and opportunity for themselves. The instructional strategies mentioned in Table 1 will help design educators to cater the GenZ (new generation) learners at various levels and needs. It is possible to validate the developed framework for instructional design in near future.

Table 1. Strategic and instructional solutions to problems encountered by design students.

SL. No	Problems encountered (design education)	Strategic/Pedagogic solution
1	The learner thinks the teacher will teach; the teacher thinks the learner will learn. Both take these facts for granted	Only when the student is confident and ready to use his learnings to problem solve, the teachers' job is successfully done
2	An instruction may evoke a good learning outcome but the individual performance of learners may not be enhanced	Every instruction given, should offer the relevance of the learning outcome citing examples to illustrate application

(continued)

Table 1. (continued)

SL. No	Problems encountered (design education)	Strategic/Pedagogic solution
3	Current students remain too distracted to get involved	Teachers who are empathetic to their learners get bracketed in the 'respected friends' category thus creating a teacher-learner rapport
4	Learners may be inhibited in their creative pursuits	Sensitively and systematically, demolishing the preconceived notions/mental blocks, pushing unconstrained futuristic thought
5	Undesirable academic behaviour	Offer reinforcement (increase behavior) of desirable traits & punishment (decrease behavior) of undesirable traits. Repetition of such behavior creates good habits of learning
6	Doubting self-capabilities	Developing self-confidence to overcome insecurities and short-comings. Encourage and support their thoughts with arguments
7	New Topics/subjects are considered invincible monsters	Introduce new topics and aspects in friendly and simple terms, building informal relationships between the learner and the subject matter
8	Lack of interest in exploring the subject. Learners normally study subjects to pass exams and carry no recollection afterwards to allow for fruitful application	Build relevance of each subject with daily life happenings offering exploration through challenging exercises. This motivation leads the learner to begin his own exploratory journey
9	Differently abled (DA) students - • ADHD (Attention Deficit Hyper-activity Disorder) • Hearing impaired • Speech impaired • Physically impaired	DA learners need to be facilitated with additional support for design education. For ADHD students, being seated closer to the teacher, repeated directions, short quizzes and notes/lesson, colorful teaching aids, etc. For Hearing & Speech Impaired more graphic and illustrative Instruction and communication using hand gestures, drawing and other visual methods. For the Physically Impaired, simplification of assessment methodology, creating supportive infrastructure and respecting their handicap
10	Learning being facilitated in the absence of the recognition of the social context	Help establish the social context connect in which the learning needs to happen for the learner

(continued)

Table 1. (continued)

SL. No	Problems encountered (design education)	Strategic/Pedagogic solution
11	Indifference of the teacher to level with where a learner is with his/her understanding	Teacher should build the bridge of communication from where the student is located in his understanding and not where the teacher would like to begin his instruction
12	The art of remembering once understanding has happened	Use of flow chart, metaphors, analogy in the teaching learning process
13	Sensitizing students to design approach, knowledge building	Methods of sensitization to the fundamentals of design thinking
14	If the three forms of readiness - teacher, curricular and societal are not in perfect alignment, constructivism and other reform movements are sure to fail	Building correlations and relevancies in the learning process by aligning the Teacher, curriculum and social construct
15	There is confusion and even frustration as the learner is not easily able to contextualize his learning into abstractions and convert the same into knowledge and skills for himself	Allowing the learners to construct their own understanding, the instruction methodology will prove contributive to the development of the learners' higher cognitive skills
16	Learners do not find meaning/build an appropriate knowledge structure [they simply copy what the better students do]	Assessment of the learnings must focus on the learner's reasoning (synthesis and evaluation)
17	Sometimes students do not learn from each other (Peer learning)	Promoting proactivity and collaboration in the teaching/learning environment shall bring better clarity (of ideas) and help evaluate ideas of others through discussion
18	Learners are not able to grab new way of instruction delivery when it is delivered by a new faculty member	New Curricula needs to factor-in the learner's previous experience to avoid any gaps for the new learning experience, focusing on problem solving models
19	Misinterpretation of certain truths and inclusion of these into the mental structures resulting in derailment of the thought building process	Elaborate teacher-learner discussion and debate on fundamental concepts after ascertaining the level of previous understanding of the learner
20	Older generations often instigate introverted and selfish behavior amongst the younger generations citing competition due to their own insecurities	Miro- using the tool, allows collaboration virtually on a platform for the learners. Collaborative learning always builds confidence and trust amongst learners

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Role of Design Control Interventions in Ameliorating Hot Stressful Thermal Work Ambience: A Review

Milap Sharma, N. M. Suri, and Suman Kant

Abstract Hot-stressful work conditions may cause greater risk of heat-related morbidities and safety threats to users' employed; especially in developing countries having low and medium incomes. Prolonged heat stress exposure could significantly affect users' physiological response in terms of heat strain; resulting in subsequent performance-loss and further attributes to economic burden. Concerned negative impacts necessitates remedial control measures based on minimizing the associated exposure risk levels. Present study aims at depicting the efficacious role of control interventions in improving occupational heat stress under hot work conditions with environmental ergonomics perspective. Reported literature work includes studies related to implementation of engineering control interventions, role of sensor based intelligence and simulation based applications; emphasizing on ameliorating the hot stressful work-conditions. Research findings revealed that engineering based interventions could lower the heat-stress exposure levels upto desired permissible limits under the existing thermal work-conditions; however simulation studies may be helpful in suggesting appropriate design interventions based on improving thermal work ambience. Although, recent technological advancements in sensor intelligence could enable heat stress data monitoring and analysis at substantially lower cost; with additional benefits like early warning systems, real-time physiological monitoring (indicating heat strain) and automation control based on threshold limit values. With several associated benefits, it may be concluded that these control interventions could play a dominant role in significantly improving the health and safety of users' employed under hot stressful work environments.

Keywords Heat stress · Negative impacts · Control interventions · Safety

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1 Introduction

Heat stress is often an ignored occupational health hazard especially in developing countries [1, 2]. Excessive hot environments are usually wide-spread in several indoor and outdoor work-sectors such as foundries, rolling mills, glass units, construction sites, mining sites, agricultural work [2]. A research conducted in South-east Asia found that workers' involved in high heat generation/outdoor tasks like construction activities, agriculture, manufacturing, brick kilns, casting and glass units were exposed to higher occupational heat stress. Around 62% workers (from a group of 442 workers) reported loss in work productivity, where abundant group coming from the high workload occupations such as brick manufacturing, metal fabrication, construction tasks [3]. Work-conditions involving heavy physical work in hot and humid environments can put considerable heat stress on workers [1–3]. Hot and humid conditions can occur either indoors or outdoors. Heat stress impacts the human physiological mechanism, in terms of change in heart rate, skin temperature, core body temperature, and body mass loss due to sweating; which ultimately deteriorates the human health and work productivity [4]. A prolonged period of heat exposure with poor work conditions may affect the production level and at the same time, it will negatively impact the workers' performance functioning in an indoor high heat work-environment [5–7]. Heat stress disorders could vary from minor discomforts (heat rashes, exhaustion, and cramps) to chronic life-threatening issues such as immunological damages and even heat stroke [8]. According to a previous study in India during the summer season, millions of poor workers are affected by excessive workplace heat with consequent health risks, which affect the worker's productivity and daily incomes [3]. Prevalent conditions indicate urgent need of remedial control measures based on reducing the heat stress exposure. Present review provides an overview of the concerned heat stress parameters, possible negative impacts; with special reference to studies (from the past decade) implementing design control interventions based on improving the existing thermal work conditions. In present approach, relevant articles and publications have been searched from leading literature databases i.e. Scopus, PubMed, Science direct, and Google scholar. For searching strategy keywords like heat stress, hot work environments, worker health and safety, control interventions, sensors have been used.

1.1 Attributable Factors

There are few major heat stress factors classified into two main categories [4, 9]; measurable environmental factors like air temperature, globe temperature, relative humidity, air velocity and two personal factors i.e. metabolic rate and clothing insulation as described in Fig. 1. Air temperature is one of the main factor of importance while considering thermal stress. Radiant heat gains due to the presence of radiant sources like brick kilns, furnaces, boilers and solar radiations leads to heat disorders,

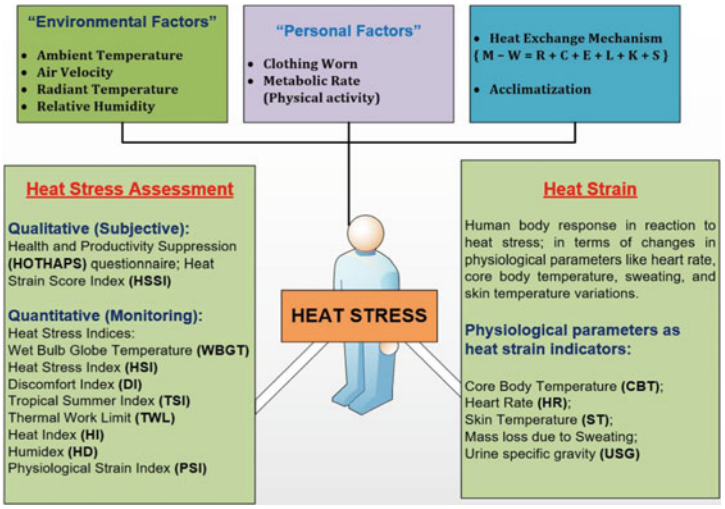

Fig. 1 Important aspects in heat stress

as it greatly affects the heat exchange mechanism between user and its surroundings. Relative humidity (RH) is of great importance as a higher humid work environment would prevent the sweat evaporation from the skin surface, which could result in increase of user's core body temperature (CBT). Air flow surrounding the user is desirable for relieving thermal stress under the concerned work environment. Still air results in heating up of the work environment, whereas moving air supports heat loss by convection. Similarly user physical movement results in increase of air flow, but depends on the activity level. Being warm blooded creatures, our body generates heat continuously and the rate at which this heat is generated is given in terms of metabolic rate. Usually it depends on the user's activity and given in terms of "met" (1 met = 58.2 watts/m^2). Metabolic rate depends on physical characteristics of a person and muscular work intensity level (ISO 9886, 2004) and varies for different type of activities like resting, sedentary, standing, industrial work [10]. Clothing provides insulation effect which gives resistance to heat transfer and effects the thermal strain experienced by the user. It is described in terms of "clo", where 1 clo equals to 0.155 m^2 °C/watts. If the Insulation level of clothing is too high then it could generate immense heat stress even if the work conditions are not too hot. ISO 9920 standard provides an estimation of thermal insulation and water vapor resistance values for various clothing ensembles [11]. The heat exchange between the human and its surroundings is described by heat balance equation [Eq. (1)] which relates the heat production rate to rate of heat lost [9].

$$M - - W = R + C + E + L + K + S \tag{1}$$

M is total energy production (watts/m^2), W is external work (watts/m^2); R represents radiation heat lost, C is convection heat loss, E is evaporative loss (sweating), L is thermal loss due to warm and wet air (inhaled and exhaled), K represents conduction heat loss, S is body heat storage rate. Users employed under hot work-conditions are generally prone to acclimatization; which is getting used to habitual work environment. It provides physiological adjustments to human body like increase in sweat glands capacity, decrease in heart rate and CBT as compared to non-acclimatized workers and results in increase in user's ability to tackle heat stress [12, 13].

1.2 Heat Stress Assessment

Heat stress indices have been categorized under three main categories i.e. rational indices (based on the heat exchange equation), empirical indices (relating to objective and subjective strain) and direct indices (involving direct measurements) [14]. For heat stress assessment, several indices have been developed over the past century which includes the environmental factors and personal factors or combination of both [15]. There are several other indices which also include the user physiological parameters [4]. On the basis of considered factors, we can perform quantitative analysis for thermal stress assessment using several thermal indices in force like wet bulb globe temperature (WBGT) index, Heat stress index (HSI), Physiological strain index (PSI), and Discomfort index (DI) [16]. WBGT (ISO 7243; empirical index) is the most widely used index for the assessment of hot stressful work-environments; considering combined effects of air temperature, humidity, air velocity and radiation by measuring natural wet-bulb temperature (T_{nw}), dry bulb temperature (T_a) and globe temperature (T_g) for indoor and outdoor work conditions [17]. ISO 7243 standard also considers the spatial variations among measured environmental factors at three different heights levels i.e. ankle height (0.1 m), waist height (1.1 m) and head height (1.7 m) [17]. Previous studies revealed that WBGT index could be used as an optimal heat stress index, due to its applicability in hot work environments [3, 18–20]. But, merely relying on a single index could not provide appropriate in-depth analysis. So, it may be used as an initial screening method followed by evaluating the physiological parameters based on the recommended standards or also in conjunction with other widely used indices. With the help of these indices, one could assess the heat stress and optimum thermal comfort level under the targeted workplace for better workmanship. However, for assessing the users' thermal perception, subjective assessment tools (qualitative assessment) like High Occupational Temperature: Health and Productivity Suppression (HOTHAPS) questionnaire, Heat strain score index (HSSI) could also be used [18, 21]. Heat strain is the human body response to heat stress; indicating changes in physiological parameters like sweating, heart-rate (HR), CBT, and skin temperature variations [4, 13]. There are various valid indicators of heat strain (such as skin temperature, HR and CBT) which reflects the changes in human body physiological behavior, while experiencing harsh stressful thermal conditions. Several other indicators include body mass

loss due to sweating, urine specific gravity (USG) reflecting the dehydration level experienced [18]. However, due to associated psychological annoyance with some indicators, measurements procedure could be complex yet effective for conducting in-depth analysis. Several thermal indices are evaluated based on these physiological variables, one such example includes Physiological strain index (PSI) which reflects the thermal strain experienced by user using HR and CBT [22].

2 Negative Impacts

Prolonged heat stress exposure has several associated negative impacts on user well-being including work-productivity loss, heat-related health suppressions and financial burden. In few developing countries, the relationship between occupational high-heat exposure and its possible health impacts has not been clearly well established [1–3, 8]. Studies related to this occupational hazard are limited because of several challenges and economic constraints [2]. Kjellstrom et al. [1, 23] stated that climate change results in reduced work capacity in heat-exposed work environment and found this as a major issue for developing countries in achieving economic and social development. It was analysed that work capacity rapidly reduces, as WBGT exceeds from 26 to 30 °C. Krishnamurthy et al. [18] evaluated the negative impacts of heat stress on workers' health and productivity under high heat industries in southern India and determined the workers' dehydration status. Around 90% of WBGT index values exceeded the TLV limits and 70% of workers reported change in urine color and volume indicating dehydration/lack of periodic fluid consumption. Another study suggested a positive association among the hot climatic conditions and heat related occupational injuries, with possible negative impacts involving fatigue, psychomotor performance loss, reduced concentration, and lack of alertness [24]. Venugopal et al. [25] reported that apart from occupational heat-related morbidities, the issues of damages at sub-cellular level (DNA damage) is prevalent among workers exposed to high working temperatures. Beheshti et al. [26] evaluated exposure of thermal stress and its subsequent performance-loss among workers functioning under high-heat indoor work conditions. It was concluded that extreme workplace heat could significantly decrease the labour work performance and consequently their production capacity. Ismail et al. [5] examined the impact of indoor environmental variables on worker productivity inside an automotive industrial workstation and concluded that workers' production rate is greatly affected by the RH and WBGT temperature. Prevalent limitations necessitates the urgency for appropriate remedial control measures based on improving the thermal work ambience and users' wellbeing.

3 Role of Remedial Control Interventions

The role of remedial control interventions could be considered beneficial in improving the thermal ambience of a work environment, which may include engineering control interventions (like improving ventilation design, installing reflective thermal barriers), designing optimized cooling-vests, simulation based control studies and even implementing sensor based intelligence [6, 7, 27–35]. These design control interventions may be taken as an effective and important control measure in reducing the exposure levels upto the desired permissible limits [27]. In present review, several research literature (studies utilizing remedial control measures/methods for ameliorating heat stress) have been tabulated from three different domains i.e. CFD based thermal comfort simulation studies, engineering control intervention studies and studies implementing sensor based intelligence for improving the thermal work conditions.

3.1 CFD Simulation Based Approach

Computational fluid dynamics (CFD) in conjunction with 3D-CAD design modelling may prove to be effective in analysing the existing work conditions and proposing design models based on improving the thermal work ambience [28, 29]. Nowadays, several leading software packages (like ANSYS Fluent, Simcenter Nastran, Solidworks, and Simscale CFD) are available in the market; which allow user to perform thermal comfort based simulations in an effective manner. Various researchers have implemented this approach to analyse the thermal work ambience under different environmental conditions such as residential buildings, classrooms, kitchen, manufacturing industries and so on [6, 28–30]. Different studies describing the efficacious role of simulation based strategies in ameliorating thermal work ambience has been described in Table 1.

3.2 Engineering Control Interventions

Engineering control interventions like ventilation design, installing reflective thermal protective shields, cooling vest design may prove to be effective in controlling the thermal stress exposure at the workplace [7, 31–34]; as depicted in Table 2.

Table 1 Studies related to thermal comfort based CFD simulation

Authors/Year	Work environment	Methodology	Proposed design/Key findings
Lin et al. [28]	Air-conditioned Lecture Room; Malaysia ANSYS Fluent	Investigating the indoor air flow inside separate lecture rooms; having two different air-conditioning configurations (split and centralized units) through CFD simulation approach	Altering position orientation for split AC units inside the lecture room to obtain a better air flow pattern. Centralized unit provided a better streamlined air-flow distribution. Changes in Split unit orientation indicated a better air flow pattern inside the lecture room
Sugiono et al. [6]	Manufacturing Industry; Indonesia ANSYS Fluent	Analysing workers' thermal comfort level; employed in a plastics manufacturing industry based on PMV-PPD calculations and suggesting CAD based design modifications followed by CFD simulation focused on improving the worker thermal comfort level	Replacing existing ceiling glass material; from clear glass to reflective clear glass (6 mm thickness; with 23% transmittance). Proposed 3D-CAD modifications indicated decrease in ambient temperature by 4 °C; whereas predicted mean vote (PMV) decreased by 0.64 point and predicted percentage of dissatisfied (PPD) showed 13.8% increase in thermal comfort
Kamar et al. [29]	Non-air conditioned Mosque building; Malaysia ANSYS Fluent	In present study, authors used CFD based design strategy for improving the thermal comfort inside a large spaced mosque building. Field measurement followed by 3D-CAD model of Mosque building was analysed using CFD approach for different suggested design models	Author proposed four suitable design modifications: Installing Exhaust fans (with 1-m diameter) on Mosque building walls. Four cases of suitable combination were considered: Case 1 - *Roof-12 fans*, Case 2-*west-side wall-12 fans*, Case 3 - *east-side wall-12 fans*, Case 4-*south-side wall-10 fans* Installing ten exhaust fans (1-m diameter) on south-side wall at floor height of 6 m has a potential of reducing the PMV index by 75–95% and PPD by 87–91%

(continued)

Table 1 (continued)

Authors/Year	Work environment	Methodology	Proposed design/Key findings
Alam and Salve [30]	Non-air conditioned Railway Pantry Car; India ANSYS Fluent	Present study aimed at enhancing the thermal work conditions inside the Railway Pantry Car Kitchen. Onsite field measurements followed by analysing proposed 3D-CAD based design modifications using CFD approach	Author proposed four design modifications for pantry kitchen: Case 1- *4 Exhaust fans (front wall), 2 Carriage fans (roof);* Case 2- *4 Exhaust fans (front wall), 2 Carriage fans (left and right side wall);* Case 3- *4 Exhaust fans (front wall), 4 air vents (lower front wall);* Case 4- *4 Exhaust fans (front wall), 3 Carriage fans (bottom surface)* CFD results revealed that case-I design model provided a better design concept by improving air ventilation and de-creasing the indoor ambient temperature during all cooking periods as compared to the existing and other case models

Table 2 Studies related to design control interventions

Authors/Year	Work environment	Methodology	Control intervention/Key findings
Mohammadyan et al. [31]	Foundry Industry; Iran	To reduce heat stress exposure levels among workers employed in a foundry industry	Designed cool spot for workers Implemented design intervention resulted in reduction of the WBGT from 29.6 to 22.8 °C, and MRT decreased from 43.8 to 28.6 °C; thereby reducing the heat stress exposure among workers
Hajiazimi et al. [32]	Steel Foundry Plant; Iran	To control heat stress exposure level among workers in foundry unit of an Iranian steel plant. WBGT measurements were performed before and after implementing control plans	Author proposed installing double layered reflective protective shields to reduce the radiant heat exposures among workers Experimental results revealed reduction in radiant temperature from 44.04 to 35.8 °C and decrease in WBGT value from 28.88 to 26.57 °C

(continued)

Table 2 (continued)

Authors/Year	Work environment	Methodology	Control intervention/Key findings
Giahia et al. [33]	Steel Plant; Iran 20 Male Smelters	To reduce radiant heat exposure generating from a blast furnace utilizing engineering control interventions followed by analysing the efficacy of the control interventions using heat stress indices and workers' core body temperature (CBT)	Implemented a heat absorbing system (cooling tower with water circulation) in the furnace body and installing steel framed structure (with multilayered reflective Aluminum covering) in the workstation. Using both interventions, the MRT and WBGT value decreased by 26.5 and 5.2 °C; while the workers CBT reduced by 2.6 °C
Huda [7]	Electronic manufacturing plant; Indonesia 11 industrial workers	To analyse and improve the effect of environmental conditions on workers thermal comfort by reducing the predicted percentage of dissatisfied (PPD) among employed users	Proposed ventilation design using direct evaporative air cooler as an engineering control to improve the work place condition. After implementing the proposed engineering control intervention, PPD value predicted by CBE thermal comfort tool reduced to 34% and also HSI reduced to 13.6 (from existing HSI value of 52); indicating improvement in workers thermal comfort
Zare et al. [34]	Laboratory Environment (sealed climatic chamber); Iran 15 male University Students	Present work investigates the effectiveness of an optimized ice cooling vest and standardized paraffin cooling vest on heat strain parameters under a controlled environment	Author proposed low cost optimized ice cooling vest; hydrogel filled to increase ice-pack flexibility; polyvinyl chloride packs with ethylene vinyl acetate foam layer to prevent tissue damage. Heat strain parameters varied significantly during the experimental study between with and without wearing cooling vests. Authors observed that proposed cooling vest was as effective as commercial vest, yet also cost-effective

3.3 Sensor Based Intelligence

Emergence of modernistic sensors could enable real time smart monitoring and design control actuation systems at substantially lower cost than conventional expensive equipment's in the market. Several associated benefits include compactness, energy savings, high-reliability and precision level, quick response rate, easier integration and so on [35]. With recent technological advancements (enhancing capabilities in deploying sensor modules for workplace monitoring and predicting user thermal comfort/assessment); respective implementation concerns are gaining importance, so as to keep the targeted audience well aware about the prevalent thermal conditions [36–39]. Furthermore, several studies have implemented advanced sensor modules with microcontroller unit; to serve as low-cost data acquisition system with

Table 3 Studies related to sensor based intelligence

Authors/Year	Work environment	Methodology	Measured variables/Sensors/Key findings
Chen et al. [36]	Indoor Lab environment Single participant	Development of an arm-worn heat stroke detection device for people exercising in hot environments and generates early warning signal based on identified risk level	Heart rate, skin body temperature, ambient temperature, Galvanic skin response (GSR); Infrared temperature sensor, ambient-temperature sensor, Pulse sensor, GSR sensor Proposed device monitored the physiological data of user running on a treadmill and detected the heat stroke risk-level and alerted user their body status; thereby preventing the heat stroke occurrence possibility
Runkle et al. [37]	Outdoor Environment; USA 35 male Grounds management University workers	Analysing heat strain (involving occupational, environmental, behavioral factors) experienced by ground maintenance workers employed under outdoor work conditions using wearable multi sensor based approach	Heart rate, dry bulb temperature; Thermocron iButton, GPS-enabled wrist based heart rate smartwatch Authors observed mismatch between workers' thermal perceptions and actual heat strain experienced by the exposed audience. Higher heat strain was recorded among workers exposed to hot climatic conditions. Early heat warnings could allow the user to implement behavioural adaptive actions and keeping them well aware of the thermal conditions

(continued)

Table 3 (continued)

Authors/Year	Work environment	Methodology	Measured variables/Sensors/Key findings
Aryal et al. [38]	Laboratory controlled environment; USA 12 male, 8 female participants	Utilizing wrist-worn sensor based approach for predicting user's thermal sensation and satisfaction	Skin-temperature, air temperature; FLIR thermal imaging camera, Infrared temperature sensor, environmental sensor, GSR sensor Results revealed that environmental sensor data in conjunction with physiological sensor data resulted in thermal sensation prediction improvement of 3%–5%; as compared to environmental sensors data only
Jha and Tukkaraja [39]	Laboratory scale model for underground mining sites; USA	Conceptualization for real-time monitoring and assessment of underground climatic conditions using sensors and GIS (Geographic information system) approach	Ambient temperature, Relative humidity, Carbon monoxide; Carbon monoxide sensor, DHT11 temperature-humidity sensor Proposed design demonstrated a risk-based warning system; which could provide a safer and comfortable work-environment for users' working underground

potential benefits such as easier implementation, open source hardware/software availability, wireless sensing and actuation system [27, 39]. Table 3 depicts such related studies implementing sensor based approach for improving the individual thermal work ambience.

4 Conclusion

Heat stress is a dominant occupational health hazard especially under hot work environments; associated with several negative outcomes such as heat related illness, mental fatigue, productivity loss, and financial burden. Adequate prevention and control policies are necessary to ameliorate the hot stressful work conditions and improve social well-being of the exposed users. There is urgent need for site-specific sustainable solutions to reduce the negative impacts of occupational heat stress; rather than just relying on heat stress assessment based strategies. The adaptation measures could focus on providing site-specific sustainable solutions (industrial design, technological control interventions) based on improving the thermal

work conditions and enhancing user work-productivity. From the present review literature, it may be concluded that remedial control interventions could be considered beneficial in improving the thermal ambience of a work environment, which may include engineering control interventions (such as improving ventilation design, installing reflective thermal shields, designing optimized cooling-vests); CFD simulation based control studies based on suggesting suitable design modifications; and even implementing sensor based intelligence for analysing and controlling heat exposure at the individual level. With recent technological advancements and emergence of modernistic sensor modules for workplace monitoring and predicting user thermal comfort; respective implementation concerns are gaining importance so as to keep the individual well aware about the prevalent thermal conditions. However, there is need for additional study describing more site-specific sustainable solutions/pathways to reduce the negative impacts of occupational heat stress under high heat environments; with emphasis on improving the thermal work conditions and enhancing worker productivity. These design control interventions may be taken as an effective and important control measure in reducing the exposure levels upto the desired permissible limits.

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A Smart Compact Kitchen Layout to Optimize Space Utilization

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Abstract The present work demonstrates the development of a compact kitchen design prototype in the Indian context. With smaller spaces, nuclear families and busy lifestyles, the cooking experience needs to be more efficient and pleasant. The aim of this work is to create a compact, ergonomic kitchen layout with optimum space utilization which should be low maintenance and safe to use, and it should suit the ever-changing lifestyles of the elderly, bachelors, and working couples. The study's methodology included three components: a survey, ergonomic analysis, and design considerations. By analyzing primary and secondary data, user need statements were developed. Mission statements were used to set goals for the design. Mind mapping and concept sketch were employed for the initial ideation cycle. The second ideation cycle was used to visualize the space in three dimensions by building CAD models of the concepts. Finally, in the final ideation cycle, these concepts were screened and modified, resulting in a CAD prototype of the final concept. The major components of the kitchen include the work triangle, cabinet storage and counter space. All of them are incorporated into the design, making it sufficient to fulfill our daily requirements. The proposed design can meet the basic requirements while using the minimal space and maximizing functionality. It will suffice for nuclear families and small households serving one or two people per meal. The design is proposed to be employed in temporary set-ups in disasters and medical emergencies.

Keywords Ergonomic · Compact kitchen · Work triangle · Elderly · Efficiency

1 Introduction

The concept of comfort is associated with physical and mental well-being. A well-designed kitchen is comfortable to operate and use. A good design is rated on how well

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it responds to the space and its components being organized in a methodical manner. It should also be able to decrease the need for unnecessary tiredness and unnatural movements, making cooking and cleaning as comfortable as possible. Ergonomics is the study of the link between the human body and the environments in which we live and work to optimize movements and avoid unhealthy postures. The kitchen is one of the locations in the home where ergonomics is most important. Ergonomics aid in the creation of a practical and utilitarian place by removing discomfort and strain. The demographics of the advanced and developed world are changing. The continuous and growing impact of urbanization and the traditional joint family has changed in the late twentieth century for various reasons, including the need for some members to move from village to city or from one city to another for employment opportunities. This has given rise to elder couples and bachelors living alone and people with busy lifestyles who get little or no time to look after their homes. In such a scenario, the need for a safe, comfortable, and low maintenance kitchen becomes prominent.

The kitchen is the core and the essential premises of any home. A well-functioning kitchen is usually a vital component of living comfortably. Unlike most other rooms in the house, the kitchen serves as a workstation. Making that setting comfortable is crucial for the user's satisfaction. By enhancing the interface between the human body and the objects we need to deal with to get the job done, ergonomics attempts to make this task more efficient, quicker, more enjoyable, and less tiring.

To establish the best height for kitchen work surfaces, the anthropometric diversity of users as well as the variety of activities to be completed should be considered. Inappropriate counter height causes the individual to hunch over, putting tension on the neck, shoulders, and lower back muscles. One tends to lean forward if the elbow is too high above the work surface. Working with hands that are too high and/or too far away creates a compensating stress on the back's curvature. A low work surface develops trunk flexion and back muscular tension. Due to a lack of clearance and standing too far away from the work surface, foot posture is constrained. Toes turned out a lot when working at the corner of a counter due to constrained foot position. Long periods of time spent in an unpleasant posture result in twisting of the spine. When working at the sink, a person may have to lean, or stretch their shoulders and elbows to work above the counter. Lower back pain, neck pain, joint pain in the feet, and shoulder pain are the most common complaints among kitchen users [1].

A modern middleclass residential kitchen is equipped with a stove, sink, refrigerator (i.e., the working triangle), and kitchen cabinets. Today's kitchen is not just a place to prepare and store food and but also a multi-use interaction space in family life. The percentage of 'couple only' families has risen as the nuclear family paradigm has gained traction. Many nuclear families are opting for smaller homes and space-saving solutions, which is fueling the modular kitchen market. With home interiors gaining prominence, new concepts in kitchen décor have become popular. As per the changing times, many adults below the age of thirty tend to have a busy lifestyle and expect a limited usage of the kitchen space. Many of them live alone or share their apartment with one or two people. Their lifestyles expect spaces to be compact and highly functional. Also, considering the older people above 65 years of age, they

even require minimal usage of the kitchen space as only two people are served per meal. A large kitchen in these households is a waste of space as compared to its utility. A way to utilize the space efficiently is to get the maximum required output with the minimum use of the space.

Ergonomics is the study of a person's relationship with their work environment and how efficient they are in it. It is the process of planning or arranging workplaces and items such that they are suitable for the people who use them [2]. Ergonomics contributes to designing and evaluating tasks, products, environment, and systems to make them compatible with homemakers' needs, abilities, and limitations. Kitchen ergonomics is a recent discipline examining how the kitchens should be designed, from cooking to cleaning, refrigeration, and storing. In a kitchen, full-body movements are required, including hand and wrist movements, bending, and rising. Because the kitchen is one of the most used rooms in the house, ergonomics is extremely important, regardless of one's physical strength. As a result, while designing the kitchen, keep in mind that the heights of various surfaces, distances, and products make the kitchen area useful, effective, and promotes effortless kitchen work [3, pp. 1672]. Kitchens that are ergonomically designed balance our movements around the kitchen and lessen the amount of stress on the body while performing everyday kitchen activities, preventing physical problems due to poorly designed kitchens.

In India, the family structure is changing dramatically in the twenty-first century. Significant changes in family structure have occurred during the previous few decades. The fertility rate in India has declined, and couples have begun to have children at a later age, preferring to have fewer children or none. The longevity has grown because of advances in modern medicine, causing the elderly to outnumber the rest of the population, resulting in an increase in the number of persons in need of care. Increased urbanization is causing these changes, which is disconnecting children from their elders and leading to the dissolution of family-based support structures. Caring for the elderly appears to have other manifestations that are a result of shifting cultural norms and the resulting changes within families. The traditional responsibilities towards parents, such as the obligation to love and care for them, are becoming increasingly difficult to perform. Younger individuals leave their homes in pursuit of work possibilities and settle in faraway places. This shifting viewpoint, combined with the need for youngsters to relocate in pursuit of work, has resulted in a decrease in multi-generational family coexistence. This is especially true when extended family members who live in rural areas are left behind as children move to the cities. Disability or impairment in general functioning grows considerably after the age of 65. As the number of disabled elderly persons grows, they will require more help to maintain their independence [4]. Due to shifting family relations, the elderly are frequently obliged to prepare their own meals, which can be a difficult task given their limited mobility. The "slowing of behavior" that results in slower reaction and task performance is a common symptom of old age. In addition, as people age, their strength, vision, hearing, proprioception, and reaction time all deteriorate. When it comes to the protection of the elderly, the kitchen has a few potential danger zones:

- According to the National Crime Records Bureau (NCRB), more home fires start in the kitchen than in any other room. Cooking gas explosions are the primary cause of these incidents.
- Kitchens are also high-risk environments for falls due to deep storage cabinets, objects stored out of reach, slick flooring, and the likelihood of meals being taken to another room to consume. Falls are the most common type of injury, both deadly and non-fatal, that can severely cripple the elderly [5].
- Misuse of kitchen appliances (cooker, oven, food processor), cooking tools (frying pan, saucepan, wok), and silverware (knife, fork, plate) can also result in accidents [6].

Modular kitchens have brought about a drastic change in the home décor industry. With the decrease in space in urban areas, there is a rise in the demand for apartments and a change in people's lifestyles. A noteworthy outcome of the conception of the nuclear family structure is that kitchens are transforming into a multipurpose space that needs to be blended into the entire house. Time savings, convenience, and energy efficiency have become critical factors in the new evolution of kitchens. The comfortable and efficient use of space is driving the demand for prefabricated kitchens, which the modular kitchens readily offer in terms of aesthetic quality, functionality, and ergonomics. In the case of India, the population is growing at a rapid pace, and available space is rapidly diminishing. The modular kitchen market in India was valued at $ 206 million in 2018 and is expected to expand at a CAGR of over 27% from 2019 to 2024, reaching $ 862 million by 2024, owing to rising demand for premiumization among the middle class and the emergence of brands in this sector. With the growth of the internet, Indian consumers are exhibiting a readiness to experiment with layouts, textures, and color combinations. Premium elements such as magic corners and kitchen island designs are frequently used by customers to make their cooking experience more luxurious [7].

In this study, we have kept the above points in mind to define the context of an Indian kitchen and provide necessary solutions through a compact, optimal and functional kitchen design.

2 Objective

A compact, ergonomic design of the kitchen layout with optimum utilization of space is the prime objective of this work. The design is meant to be sufficient to serve the needs of a small household with a maximum of four people. Its layout should suit the ever-changing lifestyle. Keeping the user base of the elderly, bachelors, and working couples in mind, the design should be low maintenance and safe to use. It is expected to be designed ergonomically to reduce the energy expenditure for a better kitchen experience. Besides, it should be able to fit into a small space with foldable components to make efficient use of space according to the urban scenario. The concept is also aimed to be used in the temporary set-ups in case of emergencies.

3 Methodology

The methodology formulated for the study comprised of three major aspects- Survey, Ergonomic analysis, and Design considerations. The research involved collecting data from primary and secondary sources. First, user need statements were created by analyzing the data. Then, further refinements lead to the creation of the mission statement, thereby setting up different goals for the design. With these insights, the first ideation cycle was performed using mind mapping and creating a session and sketching the plans for the concepts. Then, a second ideation cycle was performed to view the space in three dimensions by creating CAD models of the ideas. Finally, these concepts were screened using the Concept Selection Matrix and modified in the final ideation cycle that resulted in the CAD prototype of the final concept. Materials and textures were added to the final concept. A rendered 3D model of the output using Autodesk 3ds Max 2018.

3.1 Primary Data

Several qualitative methods were employed to gather information about people's motivations, expectations, and the perceived problems in the kitchen activities. First, a questionnaire consisting of 50 questions based on the working and functional layout, kitchen chores, reach & accessibility, and kitchenware was circulated through google forms. Forty-two responses were received. It was found out that cooking is a routine activity in every household to serve the family [8]. Thirty-six responses (85.7%) were from nuclear families, where one or two people used the kitchen, and food was served to less than four people daily. The primary cook was female in 38 responses (90.5%), and the average height was about 155cms. The results were compiled to indicate the participants' problems, expectations, and the most used kitchen equipment. The participants' main problems were insufficient cabinet storage, insufficient counter space, and effort in finding/reaching the essential kitchen items. Their expectations included a small kitchen, sufficient to serve the basic functionalities, optimized use of space, adjustable cabinets, and ease of reaching the tools. The most used kitchen tools were knives, cutting boards, spoons, spatulas, and whisks. The necessary components included the work triangle, garbage disposal, and the desired electrical appliances. In addition, several participants mentioned the need for a spice rack, cutlery and tray dividers, and pull-out bins.

The analysis leads to the creation of the mission statement, 'An ergonomically designed compact kitchen for small households which identifies the primary functional need and provides an efficient cooking experience.'

3.2 Secondary Data

The research involved a brief study of the existing ergonomic interventions of the modular kitchen in India and other countries. The study helped to get an essence of the topic, to be aware of the current scenario and to find out the scope of improvement in the existing interventions.

Literature directly or indirectly related to this area of study was studied. The process aimed to collect the data regarding the ergonomics related to the kitchen. Kitchen ergonomics are heavily reliant on spatial relationships, as well as distances and interactions between zones. The working triangle principle can be used to determine these relationships. It entails organizing kitchen tasks around three primary pieces of kitchen equipment: the refrigerator (storage zone), the sink (preparation zone), and the cooker (cooking zone) (thermal treatment zone) [3, pp. 1671]. It includes all the essential activities performed in the kitchen, starting from utensils and groceries to preparing meals. This organization requires a transition between the cooking space, preparation space, and storage space. An efficient work triangle should have a perimeter less than equal to 7 m [9]. The ergonomics of the space play a significant role in ensuring the comfort of usage. The height of kitchen work surfaces and storage areas should be carefully considered to reduce stress on the cardiovascular, muscular, and respiratory systems. Physiological, cardio-vascular stress, energy expenditure, and perceived exertion should all be used in the ergonomic evaluation of kitchen work with regard to space design [9]. The storage cabinets must be easily accessible. The heights of the countertop should be ideal or adjustable to suit individuals with different heights. The optimum counter height is known to be 85–100 cm [10]. High aesthetic quality and good design inspire, excite, and serve as a catalyst for following one's passions and engaging in social interactions [11]. Some kitchen-related studies have revealed that the kitchen design and cooking activities were related to energy and health issues. The amount of energy expenditure could be calculated by kcal/d in the people working in the kitchen. This accounted for 100–800 kcal/d, which was due to variability in the degree of spontaneous physical activities. The introduction of work centers at recommended varied heights and the concept of island kitchens with sinks could save 95 h of work and 28 miles of movement per year for the homemaker. The use of semi-modular kitchens increased the risk of musculoskeletal disorders, reducing the physiological cost of work. A positive correlation was noted between tiredness and resting time, kitchen triangle dimensions, and level of tiredness. With all these insights, the data as collected, analyzed, and implemented in the developed concept.

3.3 Concept Ideation

The concepts were generated through three ideation cycles, involving generating basic ideas using mind mapping and brainstorming techniques. These were analysed

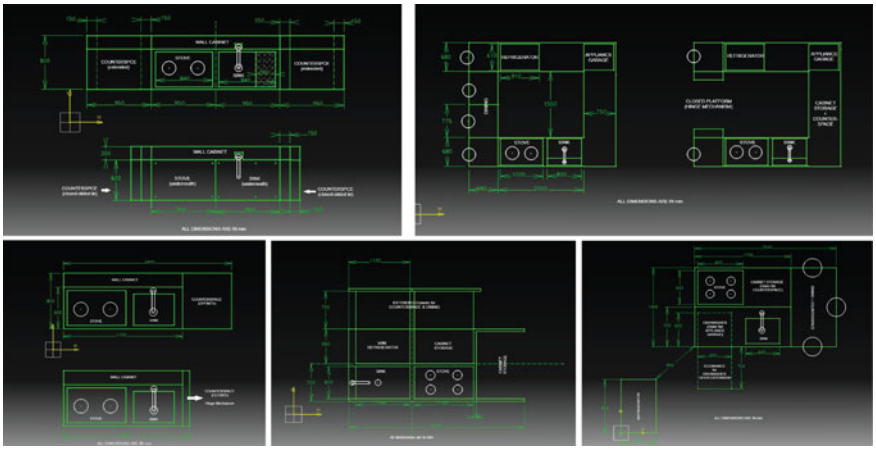

Fig. 1 PLAN Sketches of 8 different concepts

and further modified in the following cycles. The ideas generated in the first ideation cycle were represented using plan sketches, as shown in Fig. 1. Basic ideas were sketched out on paper and drawn using the sketcher tool in CATIA V5. The work triangle was an essential aspect of every idea. The worktop and cabinet dimensions were decided in accordance with anthropometric dimensions. Each idea consisted of some mechanism for the movement of the countertops, which would make efficient use of the space. These were analysed by quick-thinking and brainstorming sessions and refinements followed by implementation in the second ideation cycle.

The ideas generated in the first stage were analyzed based on the ease of implementation, work triangle access, optimum functionality and use of space. These were further modified and converted into 3D CAD models in the second stage of ideation, as shown in Fig. 2. This was done to give a better idea of the kitchen space and layout. A better analysis was possible with the 3D visualization of different concepts.

The concepts were analyzed using concept selection matrix based on the certain parameters given in Table 1. The best concept design amongst the six was chosen and modified to generate the final concept. The final concept was ergonomically designed, keeping the optimum use of space and functionality in thought.

3.4 Components

The final design included the work triangle, movable and foldable countertops, cabinet storages, and other essential components. The concepts are as shown in Figs. 3 and 4.

The components designed are compactly arranged as per ease of usage and workflow. The design can be divided into two parts. The left part for chopping and cutting

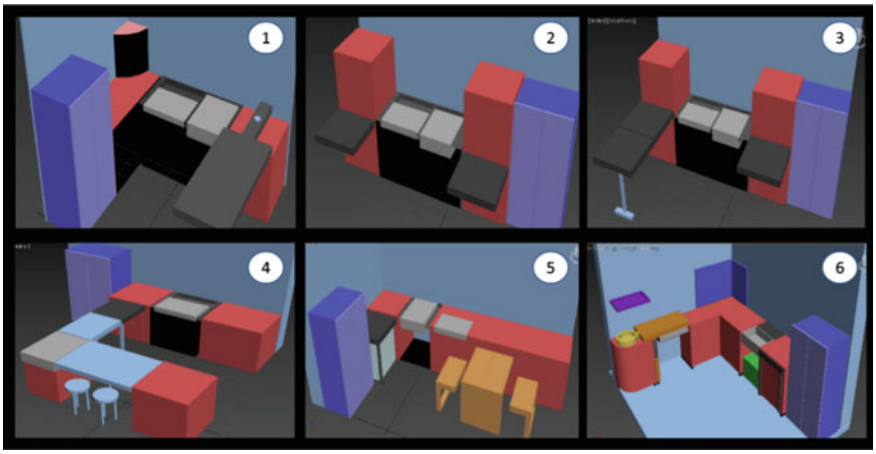

Fig. 2 CAD models of different concepts

Table 1 Concept selection matrix

Design goals	Compact	Ergonomic	Functional	Total
Weightage	10	10	10	**30**
Design 1	8	9	8	**25**
Design 2	10	8	6	**24**
Design 3	9	8	9	**26**
Design 4	5	10	7	**22**
Design 5	7	7	8	**22**
Design 6	6	6	10	**22**

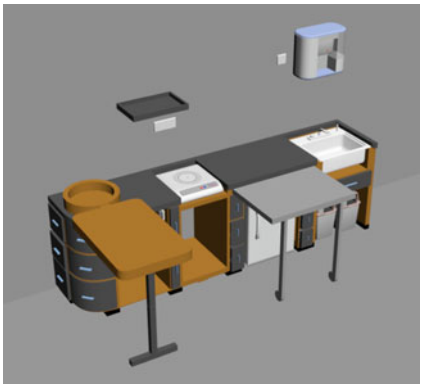

Fig. 3 Different components: countertops

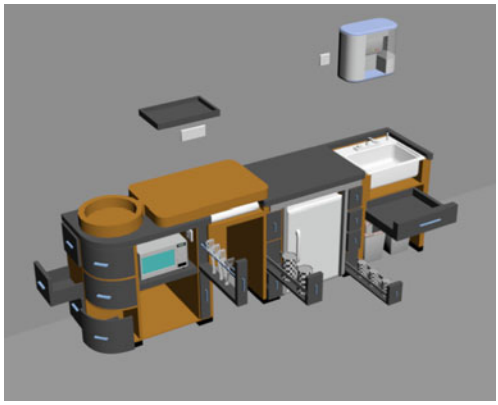

Fig. 4 Different components: cabinet storage

and the right for assembly and washing. Two movable countertops are provided, as shown in Fig. 4. One of them is rotatable and provided with a stand. The stand allows it to function as a separate countertop which can be used for chopping and cutting. It can be moved to cover the stove when it is not being used. At the same time, a stool can be retrieved from the shelf that can be used to sit while chopping or other activities. In case of an LPG operated stove, the space underneath the stove can be used to keep the LPG cylinder otherwise it can be used for storage purpose. The other countertop is a slide-in countertop, attached with wheels. It can be taken out whenever extra space is required. With a compact usage of space when not in use, these countertops offer us space for movement, function when required, and ease the installation. In terms of storage, enough 6 drawers are provided in proximity to the usage areas to ease the movement and reduce the efforts required to find the ingredients, tools, and other required items. The edge is made rounded so that the users don't hurt themselves while moving around. In addition, a spatula rack to store most used kitchen tools like spatulas, whisks, and stirring utensils is provided near the stove area. Spices are an essential element in Indian cooking. Therefore, a spice rack is provided at the point about which the first countertop rotates. On the right side, a refrigerator is placed above which is the assembly area. The space underneath the sink is used to dispose dry and wet waste. The drainage of the sink can be facilitated in the design via plumbing fixtures in regular residential use. The space for additional items like a platform for books, microwave oven, mini-refrigerator, induction stove, sink, garbage disposal, and water purifier can be modified according to the user's requirement.

This design also has applications in case of disaster relief or medical emergencies. For temporary applications, a fill tank on wheels can be attached underneath the washing station. The tank can be rolled to a wastewater area and drained (Fig. 5).

The complete model is ergonomically designed. The dimensions of the cabinets and racks were determined in an optimum manner, so that the ease of access, functionality and appropriate proximity with different zones is achieved. The length of the single straight countertop is 3 m. The counter height was 95 cm, with a depth of

Fig. 5 Rendered CAD model of the final concept

61 cm. Body clearances of length 5 cm and 1 cm are provided in the height and depth, respectively. The rotatable countertop of length 60 cm is attached to the spice rack of 40 cm diameter. A single burner stove or induction is suggested for usage as the proposed design is for use by a few people only. For the same reason, a standard-size mini refrigerator is used. In addition, a 26- inch sink is used. The other dimensions of the cabinet and counter spaces are according to the inferences from the literature review and the standard sizes available in the market.

4 Conclusion

The significance of a kitchen is well-known. Homes cannot be regarded to be well designed without a functional kitchen area that is ergonomically fit. However, this study has revealed that users face problems due to inaccessible cabinet storage, insufficient counter space, and effort in finding/ reaching the essential kitchen items. In old age, lot of movement in the kitchen takes a lot of effort by the elderly population and can lead to fatigue. A poorly designed kitchen can also lead to injuries and accidents. As per the feedback provided by elderly, we identified the primary needs for a compact kitchen which was sufficient to serve the basic functions, optimize the use of space with adjustable cabinets, and which provides ease of reaching the relevant tools. A compact kitchen layout can provide the flexibility and efficient usage of space that is desirable for this user group. The study helped us determine the compact kitchen layout and dimensions of its constituent units that would be sufficient for the user base consisting of elderly, small households, bachelors and couples.

5 Discussion

The proposed kitchen design has a small footprint but can satisfy the basic requirements with optimum functionality. It is adequate for small households of one or two people but can be extended to nuclear families. The market is also being driven by solid growth in the residential construction industry. With rising prices of real estate, residential units have become more compact. Modular and compact kitchens provide more flexibility and efficient management of space in small houses. These factors further enhance the marketability of this design. The future scope involves testing the prototype in various settings with elderly where user testing will be conducted on a physical prototype. The observations made by the researchers and the feedback of the users will help streamline the design further. For example, changes related to the arrangement of components can be incorporated at the user's convenience. Furthermore, additional appliances or components which fit the suitability of the design can be included later. Notable development can be comprehended if the portability aspect of the proposed concept, or some part of it, is achieved. This would further ease the process of installation and aid the movement as per the user requirement. Later, the quality testing, will also be conducted to finalize the materials used in the design.

The design is also proposed to be used in temporary set-ups in times of disasters and medical emergencies. However, this will represent the secondary market, the primary being residential usage.

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Driver Behaviour as an Influential Factor for Enhanced Long Distance Bus Travel Experience as Applied to Elders Doing Pilgrimages—A Survey Based Study

G. Chinmaya Krishnan and Debkumar Chakrabarti

Abstract One of the most influential factors for the overall satisfaction of long distance bus travellers is the interaction between passengers and drivers. This paper tries to find an answer whether our drivers really aware of the needs, apart from their professional (driving) training, on behavioural issues especially attitudes towards their passengers particularly elders' requirements. An ergonomic survey was conducted on 30 long journey pilgrim buses of different routes with a total journey duration of 2–7 days continuous with night halts en-route and per day travel time of 6–10 h with mini breaks in between. A set of questions was floated to find answers related to four different aspects viz. (1) satisfactory driver behaviour (cordial and interactive), (2) Do the drivers are well versed about the journey details and destinations. (3) Willingness to help on various issues as and when required and, (4) Comfortable and smooth drives without jerks while accelerating and decelerating, and was enquired on 30 passengers for each driver (selected with purposive random sampling). The number of drivers was also 30. Hence in total 900 respondents were surveyed. Responses were recorded with a five-point Likert scale towards framing a possible behaviour guideline. The results suggest that a set of remedial knowhow to handle psycho-social and physical issues relevant to elderly passengers can be framed out and drivers may be given refresher training on special care requirement; It is expected to enhance rejuvenation of travelling spirit in spite of the gradual deterioration of physical capability of senior pilgrims.

Keywords Long distance bus travel · Driver behaviour · Elderly pilgrims · Inclusive bus travel

1 Introduction

Passenger comfort is influenced by many factors, such as seat design, vibration, ambient noise, odour, temperature, humidity, and even interior colour theme [1, 2].

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Even after numerous researchers around the globe devoted there time and resources for nearly half a century, a single traveller comfort standard which manufacturers can rely full upon is still missing. Due to the complex characteristics of the concept of comfort and to make it more difficult, the subjective nature of the same, getting a consensus among researchers is far from realisation.

This paper attempts to evaluate the factor related with the drivers of these long distance buses, and the perceived comfort of passengers. The "driver" factor can be termed as unique as not much attention has been given in this area. This study aims at finding answers whether the behaviour of the drivers of a bus (very long distance travelling bus—lasts up to several days) influences the perceived comfort of passengers?, and if yes, do our drivers really need to be trained in this aspect or are they doing their job satisfactorily?

Here we undertook a feedback based field study to examine whether long distance bus traveller comfort is influenced by driving style and driver behaviour. Data was collected by using a passenger questionnaire, distributed in long distance traveller buses, in order to get the subjective views of the passengers which is the most accurate measure for the aspect of comfort.

2 Review of Literature

There are many factors concerning with the behaviour of driver of the vehicle and the comfort of passengers. The traveller comfort criteria is the most important and most necessary one to explain the association between acceleration behaviours and travellers comfort [3–6].

The standards related with assessing the comfort while travelling inside a vehicle is governed by the ones issued by ISO, and is widely considered to be one of the most popular group criteria applied—ISO-2631[7]; ISO-2631 [8] for assessing the ride comfort due to vibrations created by travelling. One of the most important aspect about passenger comfort is the pattern of acceleration due behaviours of the drivers, such as hard acceleration and deceleration.

It is found that subtle and less frequent speed changes (acceleration and deceleration) would generate greater values of comfort ratings. As there are a band of driving behaviours from subtle to strong and rapid change in speed (accelerations and decelerations) by drivers [9–11], correlations between these factors and traveller comfort is established [12].

It is evident that, most of the research on passenger comfort appears to be focused on environmental conditions such as vibration, noise, temperature and traveling postures [13–15]. According to Yi He et al. [12], researchers mostly debated the aspects of vehicle and road condition to analyse how the vibration affects the passenger's body while travelling. Considerable research is also done in separating the relationship between road surface styles and passenger comfort. All these appears to be focussing on the technical side of comfort but unfortunately the behaviour of the driver and its influence on passengers comfort especially elder passengers is not

at all concerned of [6, 14, 17]. There is a contrasting absence of research about how the driver's behaviours such as aggressive acceleration and deceleration [5] and willingness to help fellow passengers influence the perception of comfort among passengers.

To improve the bus drivers' procedures of operation and to enhance safety, numerous bus operators are willing to train the drivers, but focusses mainly on the fuel economy and safety, but passengers comfort is comfortably ignored. On a contrary note, some research such as af Wahlberg [9–11] and Jiang [17] claims that the training of bus driver behaviours may cause a bad experience for passengers. But it is a still debated topic and as comfort is a purely subjective aspect, it would be better to gain information directly from stakeholders that is passengers themselves. And for that purpose majority of researchers use questionnaire survey as the most sought after tool.

3 Methodology

This study was conducted on the basis of a questionnaire survey. The questions were asked to travellers just after a long duration journey. Survey was done on 30 different drivers of 30 different buses doing multi day duration travel (generally doing pilgrimages and conducted tours). For each driver, the responses of 30 passengers were recorded making the total respondents number to 900.The journey took a minimum of 2 days and up to 7 days maximum. The buses were taken from 6 different Indian states (Kerala—16; Karnataka—3; Tamil Nadu—3; Andhra Pradesh—6; Uttarakhand—7 and Rajasthan—5) and for each driver 30 passengers were selected and taken feedbacks from. Each days travel took around 5–10 h of duration with mini breaks in between. The buses were having seating capacity ranging from 32 to 49 seats. A set of questions was floated to find answers related to four different aspects viz. (1) satisfactory driver behaviour (cordial and interactive), (2) Do the drivers are well versed about the journey details and destinations. (3) Willingness to help on various issues as and when required and, (4) Comfortable and smooth drives without jerks while accelerating and decelerating. The respondents from each buses (samples) were selected with purposive random sampling. Responses were noted down against a five-point Likert scale towards framing a possible behaviour guideline. Regarding the age of drivers, the mean was 34.18 with standard deviation 7.54.

The first question was: "Do you feel that the driver was helpful?"; the second one was: "Are you satisfied with the overall behaviour of the driver?"; the third one was "Was the driver informative and cooperative?"; and the fourth one was "was acceleration and deceleration smooth and comfortable?". Each question was having 5 different options. 5 points for "Completely agree"; 4 points for "agree"; 3 points for "neutral"; 2 points for "not agree" and 1 point for "completely disagree". The survey questionnaire was found to be having the Cronbach's alpha of 0.803, as the measure for reliability.

4 Results

For the question "Do you feel that the driver was helpful", the average score was 2.46 which represents "Disagree". Now for the second question "Are you satisfied with the overall behaviour of the driver?" the average score was 2.37 which is again "Disagree". Similarly, for the third question "Was the driver informative and cooperative?"; and the fourth question "was acceleration and deceleration smooth and comfortable?", the scores were 2.36 and 2.16 respectively, both representing "Disagree" (Figs. 1, 2, 3 and 4).

It is also important to note the score gained by the drivers and their age. Figure 5 shows the Age versus Score.

Fig. 1 Graphical representations of the first question showing score gained by drivers. Note that majority of the scores lies in the range 2–3 which shows non satisfaction

Fig. 2 Graphical representations of the second question showing score gained by drivers. Note that majority of the scores lies in the range 2–2.5 which shows non satisfaction

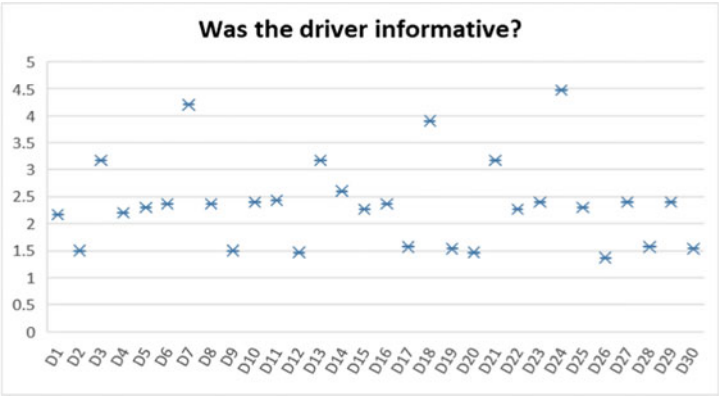

Fig. 3 Graphical representations of the third question showing score gained by drivers. Note that majority of the scores lies in the range 2–2.5 which shows non satisfaction

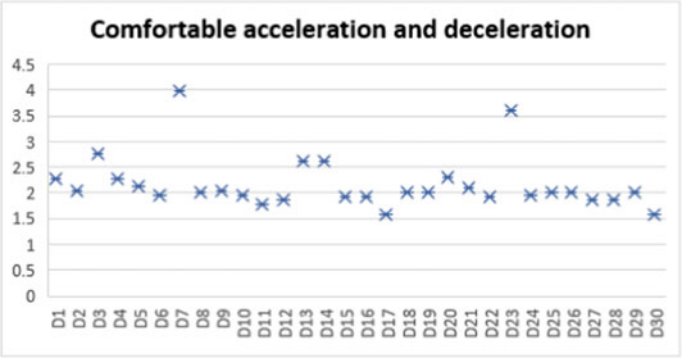

Fig. 4 Graphical representations of the fourth question showing score gained by drivers. Note that majority of the scores lies in the range 1.5–2.5 which again shows non satisfaction

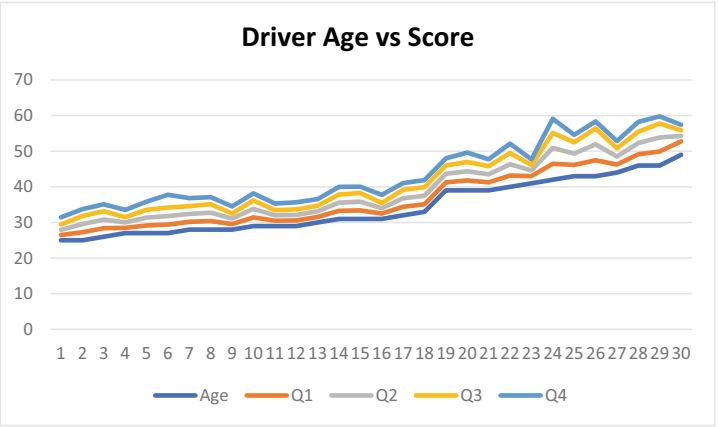

Fig. 5 Driver age versus score—it shows the positive influence of age on satisfaction levels. As the age of the driver increases the satisfaction levels of the travellers also rises

5 Conclusion

The average score attained by the drivers for all the four questions were in the range 2.16–2.46, showing "disagree". It points towards the pronounced dissatisfaction existing among long distance bus travellers due to driver behaviour. Hence it can be safely assumed that the driver behaviour affects the aspect of perceived comfort of passengers.

Also, it is very interesting to see the relationship between age of the driver and score. As the age rises score also rises. It might be due to the gained maturity of the driver with rise in age. Also, all the drivers who got scores above 4 for all the questions were have their age greater than 40.

In conclusion it is evident that our long-distance drivers definitely need to be trained specially to handle elder passengers. People who are spending many days for activities like conducted tours and pilgrimages, will definitely expect more polished and comfortable behaviour from their drivers.

6 Future Scope

This study mainly focussed on the subjective aspects only. For example, the aspect of comfortable acceleration and deceleration, were measured using feedback only. More dependable measurement techniques are available to accurately measure these factors, though the "comfortable values" of these are still under debate.

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An Ergonomic Evaluation for Designing Workstation for Fish Vendors

P. Jordan, Priyanka Sen, Purti Barve, Rhea Mirje, and Debasis Haldar

Abstract Fish and seafood has a significant impact on local culture and economy. The main activities of fish vendors like carrying, weighing, washing, scaling, and cutting are manual in nature including high physical workload. Previous studies revealed that 50% of fish vendors suffered from Musculoskeletal Disorders, 35% from fish handler's disease and 60% from skin diseases. Therefore, the implementation of ergonomic principles in the workstation of fish vendors is an important part of comprehensive health and safety processes as well as to improve worker's productivity. The present study is focused on analyzing the existing workstation of the fish vendors and to minimize work related disorders. The study also proposes a concept design of the workstation to improve worker's productivity. The data was collected in Gariahat Fish Market, Kolkata, West Bengal, India. Modified Nordic Questionnaire, RULA analysis and Quick Exposure Checklist (QEC) were used to evaluate ergonomic risk factors associated with the level of exposure to Musculoskeletal Disorders (MSDs). Result shows that 59.37% experienced pain in hand and wrist, 37.5% experienced pain in lower back, 31.25% experienced pain in their neck, 100% had cuts, 90.6% vendors confirmed that their skin was directly exposed to ice and most of the body parts are in high exposure level to MSD. The proposed design of the workstation would not only incorporate most of the work related problems but also make their work more efficient and productive.

Keywords Workstation design · Posture analysis · MSD · Anthropometry

1 Introduction

In Kolkata, fish and seafood represents a huge chunk of the local culture and economy. There are a huge number of local vendors, fishermen and businessmen involved in this process. In the fiscal year 2018, West Bengal produced 1.6 metric tons of fish and there are a huge number of local vendors, fishermen and businessmen involved in this process contributing to a large chunk of the economy [1, 2]. The Gariahat

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Fish Market is one of the largest fish markets in Kolkata providing daily business to over 80 fish vendors [3]. These fish vendors are aged between 25–60 years and have 6–10-h long work shifts on a regular market day.

Upon further desk research it was noted that fish vendors experience occupational problems such as musculoskeletal disorders, Fish Handler's disease, multiple skin related problems and hygiene issues due to poor infrastructure, unregulated workspace environment and lack of awareness regarding physical posture, healthcare and sanitation. This reduces the productivity of these vendors over time resulting in a direct impact on their business and wellbeing as they depend on daily earnings [4].

Ergonomics looks at not just the passive environment, but also the specific advantages of the human operator and the contributions that can be made if a work environment is designed to allow and enable the individual to use his or her abilities to their full potential. Harmful physiological activities in an ergonomic sense such as lifting heavy weights, hyperextending back, neck and arms to perform tasks, repetitive actions, use of force and direct interaction with chemicals due to lack of tools and mismanaged workspaces lead to a compromise of safety, health, comfort and efficiency of vendors in the work system. This ergonomic study delves into the occupational problems faced by fish vendors and aims to suggest user centric workspace design to enhance productivity by reducing physical and cognitive load [5].

2 Methods

2.1 Worker Selection and Data Collection

The data was collected in Gariahat Fish Market, Kolkata, West Bengal, India. Simple Random sampling was used to select 32 fish vendors from the market. A number of data collection methods were used including one-to-one conversation, questionnaire, RULA, QEC, WERA and observation for a period of three days. These methods were chosen as they helped us evaluate the exposure of individual workers to ergonomic risk factors associated with Musculoskeletal Disorders. The questionnaire was designed with the intent to gain insights on the lifestyle of Fish Vendors including details related to commute, posture, workspace, equipment, tasks performed and overall health.

2.2 Tools Used in the Research Process

Questionnaire. A questionnaire is a research instrument consisting of a series of questions for the purpose of gathering information from respondents [6]. Types of

questions used include yes/no questions, short answer questions, multiple choice questions and rating scales.

Rapid Upper Limb Assessment (RULA). RULA (rapid upper limb assessment) is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported. This tool requires no special equipment in providing a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body [7].

Quick Exposure Checklist (QEC). QEC has been designed to assess the changes in exposure to musculoskeletal risk factors of the back, shoulders and arms, hands and wrists, and neck before and after an ergonomic intervention. It was constructed to assess the risk of a single work task at a time [8].

3 Results and Discussion

The following subsections discuss the observations made and their inferences with respect to the research methods followed.

3.1 Questionnaire

The questionnaire was divided into seven sections namely Demographic, Commute, Posture, Workspace, Equipment, Tasks and Health. The following sections highlight the insights gathered regarding each aspect.

Demographic. Most Fish Vendors (N = 32) are aged between 30–60 years. They have been working in this occupation for a period between 10 years to as much as 35 years. About 37.5% vendors work for 6–8 h and 62.5% work for 9–10 h. On an average, their height is 169.37 cm and their weight is 62 kg.

Commute. 100% of the vendors have a middleman/assistant from where they source their daily stock of fishes. They travel for 45 min to 2 h daily to reach the market which is found to be strenuous by most of the vendors. An average of 40 kg of fish are carried by each of the vendors and brought to the market. Some vendors bring as much as 60 kg too. Most vendors in the pre COVID scenario would travel by trains to reach the market. But the pandemic has forced most of them to travel by trucks, lorries, bikes, mini trucks/vans, etc.

Posture. Since the vendors use an Iron Blade to cut, slice and clean the fishes, they sit with each of their legs on either side of the Blade, with their feet flat on the ground. 28.1% did not take any breaks during working hours. 25% of the vendors had to

extend their arms forward uncomfortably on a regular basis while the rest had to sometimes.

Workspace. The vendors sit on a short stool with the crates of fishes surrounding it. They sit on this elevated surface to keep themselves dry from the water melting from the ice that is used to store the fishes. Cutting the fishes with the Iron Blade becomes easier when they sit on the stool. Some even use bricks to provide elevation. The fishes are stored on ice or in ice boxes/fridges. Boxes of multiple vendors are stacked up and placed near to their workstations.

Equipment. An Iron Blade, known as *Boti Knife* in Bengali, is used to cut, slice and clean the fishes along with a hammer. The vendors find the grip of their tools fairly good but most say that this is because they have been using the same tools for more than 10 years and are hence comfortable with it now. Most of the vendors rated the weight of the tools a 4 out of 5 (1 being Light and 5 being Heavy).

Tasks. Tasks performed by fish vendors include cutting, scaling, washing, cleaning and weighing. Repetitive action is involved in tasks involving cutting and scaling. The frequency of the action is 10–20 times per minute.

Occupational Health. Most occupational health problems include pain in different parts of the body (Fig. 1) and various serious skin related problems.

When skin is exposed to chemicals used for storage, the vendors resort to washing it or applying natural ointments and certain home remedies. Many vendors confirmed that they did not experience any pain or discomfort as they were used to the posture and the position of working and their body had adapted to the workspace over the

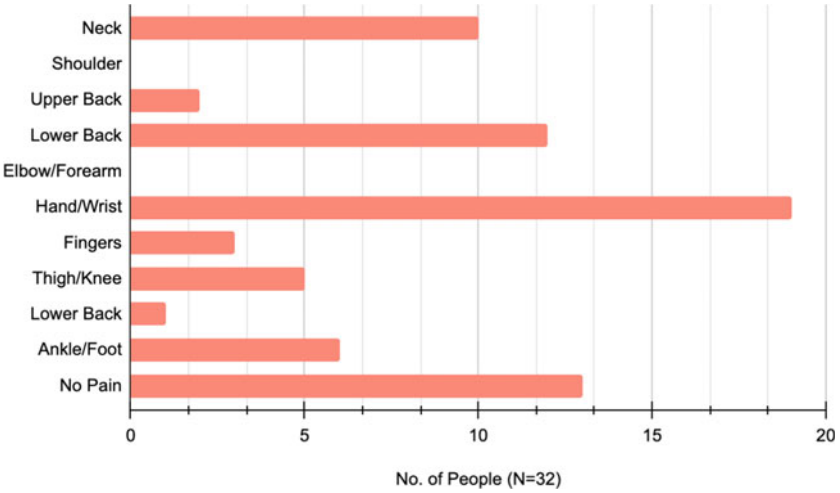

Fig. 1 Represents the number of people facing health issues associated with different body parts. A sample space of 32 fish vendors was considered for this

years. All vendors collectively agreed that their skin was exposed to ice and 90.6% vendors confirmed that their skin was exposed to ice for a maximum amount of time.

3.2 Rapid Upper Limb Assessment (RULA)

An average RULA score of 7 was obtained by analyzing 32 vendors. (Section A: Upper Arm = 5, Lower Arm = 3, Wrist = 3, Wrist Twist = 2, Muscle Score = 1, Load = 0; Section B: Neck = 2, Trunk = 4, Legs = 1, Muscle Score = 1, Load = 0).

RULA Scoring: 1–2 = Acceptable Posture; 3–4 = Further Investigation, change may be needed; 5–6 = Further Investigation, change soon; 7 = Investigate and implement change.

The scores (Average RULA score of 7) are high as the vendors are required to lean and work most of the time due to unequipped workspaces which requires the fish vendor to perform repetitive actions making it a suitable scenario requiring an immediate ergonomic intervention (Fig. 2).

3.3 Quick Exposure Checklist (QEC)

The Average QEC score obtained was as follows: Back = 34, Shoulder/Arm = 40, Wrist Hand = 34, Neck = 17, Driving = 9, Vibration = 1, Work Pace = 4, Stress = 4 (Table 1).

It is observed and assessed that shoulders, neck, back and wrist/hand undergo most of the strain. Excessive strain is caused due to long travel and work hours. While stress and work pace levels remain moderate, overall tasks are exhausting for the Fish Vendors. Visual requirement is high and vibration is minimal. Excess load is also carried by the vendors which results in an increase of the QEC scores (Fig. 3).

4 Concept

The following subsection describes a novel concept which includes workspace redesign along with two of its components. This intervention suggested by the researchers aims to jointly improve the working conditions and health of fish vendors.

Fig. 2 Fish vendors that were considered for calculation of RULA Score

4.1 Workspace

The Fish Vendors sit in a cramped up space which leads to uncomfortable working positions over long hours. According to our questionnaire, vendors work for more than 9 h. Suggested below (Fig. 4) is an improved plan of the workspace including the essential equipment such as the Iron Blade, stool, scaling box, digital weighing scale and the new, suggested display crates and waste collector. This plan includes a horizontal working space with extra storage area. This plan is designed to provide a greater radius of accessibility.

Drainage system (6-in. channel is created on the top edge of the platform) to avoid slippery floors and maintain hygiene. A niche for the crates to fit it. This will help stabilize the crates and height of the crates will be more suitable for the vendors. A niche at an appropriate level should be provided, this will act as a sink for the scaling process as vendors often turn their back excessively as the scales might fly on the

Table 1 QEC values obtained and their implications assessing the risk factors of the vendors

	Exposure Level			
Score	**Low**	**Moderate**	**High**	**Very High**
Back	10-20	21-30	31-40	41-56
Shoulder	10-20	21-30	31-40	41-56
Wrist/Hand	10-20	21-30	31-40	41-56
Neck	4-6	8-10	12-14	16-18
Driving	1	4	9	-
Vibration	1	4	9	-
Work Pace	1	4	9	-
Stress	1	4	9	16

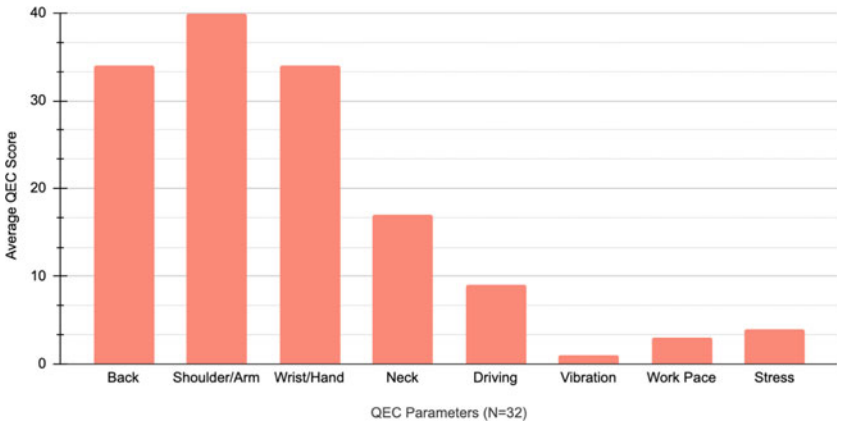

Fig. 3 Graphical representation of Average QEC Score for different parts of the body (QEC Parameters). A sample space of 32 fish vendors was considered for this

customer causing distress. This will also help keep the workspace clean. A 2-in.-deep slot below the Iron Blade for the collection of waste generated while cutting the fishes is suggested.

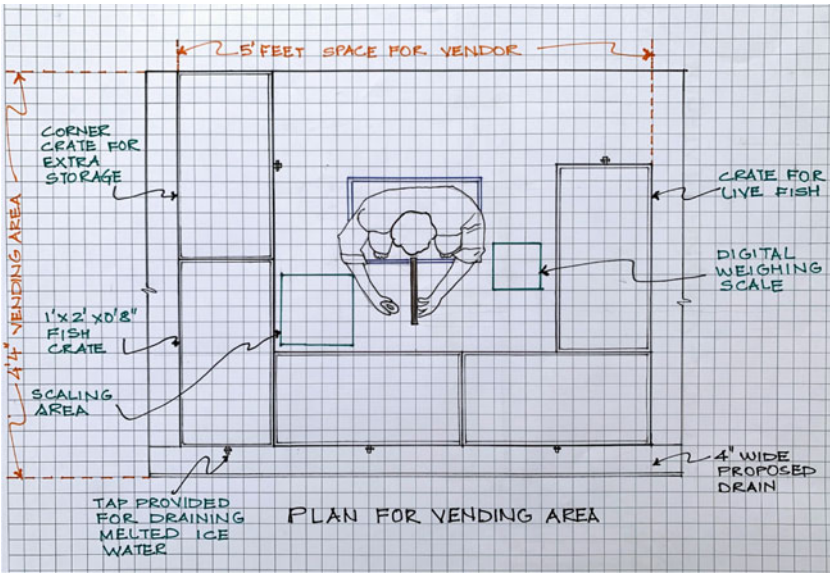

Fig. 4 Suggested plan for the vending area

4.2 Crates with Disposable Water System

The crate is translucent so the vendor can see the stock available and take possible measures. These crates will be placed according to Fig. 5. Each crate is equipped with a sieve-like slab which has holes every 1 in. to drain the melting water from the ice which will be placed on the upper compartment. The bottom of the crate has a sloping slab with a tap on the side for the water to drain out of the crate at the end of the day. The tap can be either on the length or the breadth of the crate, according to the vendor's requirement. This cuts down on the effort of lifting and tilting the crate to drain out water. Even if the bottom is sloping, the crate will have an upright structure. The crate is 8 in. tall which is at the knee level of the vendor when he sits. So the range of the angle of motion will be between 30° and 60° which will keep the back straight and reduce unnecessary strain on the back. The length of the crate is 2ft, so the vendor doesn't have to extend his arms to a wider range, this causes less strain on arms and shoulders. The crate provides thumb rest just above the handle with rounded edges for a firm grip which decreases the chance of the crate falling or sliding from the vendor's hand. The crates are stackable and won't take much storage space. These crates maintain a clean and hygienic workspace.

Dimensions: 2 ft. by 1 ft. Height will be 8 in.

Material: Polycarbonate Plastic (Translucent).

Approximate weight: 700 g (Fig. 6).

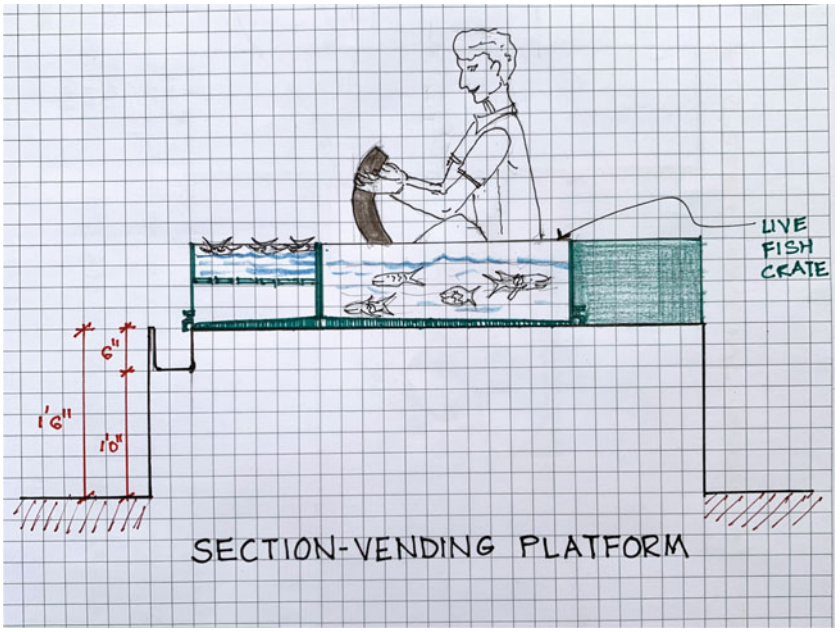

Fig. 5 Suggested elevation for the vending area

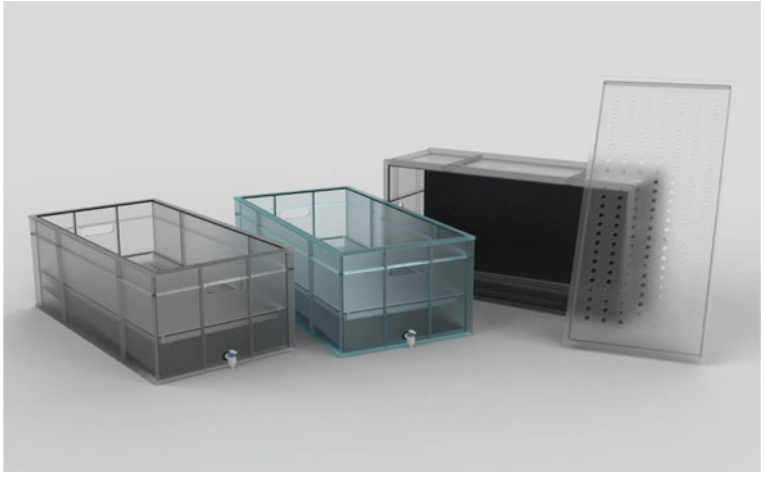

Fig. 6 Rendered models of the suggested crates

4.3 Ergonomically Designed Tool for Accessibility

The main purpose of this tool is to help the vendors access the fishes that are kept at a distance. According to the RULA analysis we aim at reducing strain on the trunk which is caused due to excessive bending/leaning. Strain on the arm is reduced as it helps ease the extended arm position. Often while bending forward, the vendors tend to lean on their wrists to reach out to fishes kept at further distances. While picking up the fishes kept on ice, fingers go numb and often cause skin related diseases. This tool will help pick up the fishes with zero contact with ice and hence reduce skin related problems. The handle has groves for a better grip and a thumb rest. Has a clamp mechanism. The rotatable lock holds the handle into place so the user doesn't have to worry. Rubber pads are curved inwards according to the natural form of the fish which holds the fish in place. The tool is lightweight and extendable which easily allows the vendors to easily access the fishes without leaning excessively or asking the customer to give the fish.

Dimensions: The tool will be approximately 1 ft long.

Material: Aluminum rod, Rubber padded scooper and Rubber grip.

Approximate weight: 250 g (Fig. 7).

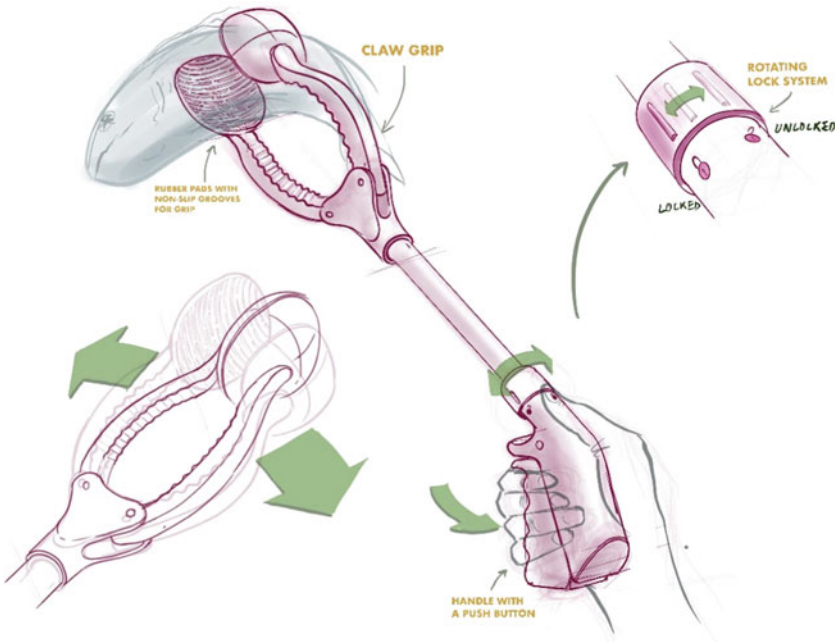

Fig. 7 Digital sketch of the suggested accessibility tool

5 Limitations and Future Scope

The current study was conducted in Kolkata, where the sample size is 32 and the data was collected from a specific area of the city. This study has evaluated ergonomic risk factors of the fish vendors and according to the evaluation report we are only suggesting the ergonomic design implementation in the workplace of the fish vendors. In this study we have not done the usability test of the suggested design implementation.

With further research, the team intends to study different materials to explore the possibility for making the crates sustainable and eco-friendly. We hope to prototype the tools, set up the workspace and conduct ergonomic evaluation of the redesign along with user testing over a larger sample space.

6 Conclusion

This study has highlighted some of the concerns associated with the health of the fish vendors. Different research methods were used to perform a thorough study about musculoskeletal disorders, skin diseases and hygiene among the fish vendors. This data could be used to design a better workplace and related tools, which would integrate solutions to all the mentioned problems faced by them. The study also recommends a few concepts that might improve productivity, efficiency and comfort of the fish vendors.

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Contributing Towards Blue Economy with Ergonomic Assessment of Musculoskeletal Disorder (MSD) Among Workers Involved in Harvesting Living Resources

Rajat Kamble, Sangeeta Pandit, and Avinash Sahu

Abstract Blue Economy is a marine-based economic development leading to improved human wellbeing and social equity. One such area is the harvesting of living resources, which requires different processes involving manual material handling. One such process is loading large quantities of crates filled with fish and ice to the truck. Repetitive work involving heavy lifting and bending results in the development of musculoskeletal disorders among the workers. The purpose of this study is to identify the health risks involved in this occupation and ultimately aid in the direction of improving the lives of the workers. Nordic questionnaire, Dutch Musculoskeletal Questionnaire (DMQ) and observation study was used to identify musculoskeletal disorders and potential work hazards the workers are exposed to in the fishing industry. A total of 30 workers were selected for this study. In total, 84% reported complaints in Lower back, 76% complaints in shoulders, and 89.6% of the workers reported complaints in Wrist during the past 12 months. Among all workers, 45% visited a physician at least once, and 30% took at least one period of sick leave. The potential work hazards were found to be repeated motion, work involving bending, lifting and wet and cold grip. Working conditions involving cold and wet grip and repeated lifting and bending motions for long hours are important risk factors for the development of MSDs among the workers working in the fish crates loading process, and thus these risks have to be eliminated with effective intervention in this area.

Keywords Blue economy · Fisheries · Musculoskeletal disorders · Manual material handling

1 Introduction

Workers in many industries get exposed to Work-Related Musculoskeletal Disorder (WRMSD) from the different risks factors involved in their tasks, Repetition, Force,

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awkward Posture and vibration being the main risks involved [1]. The fishing industry is one such industry where similar tasks with the risk of WRMSDs are involved. It is a fast-growing sector in India, Providing nutrition and food security to the people and income and employment to more than 14.5 million people [2]. India is the second-largest fish provider globally, with a total production of 13.7 million metric tons in 2018–19 [2]. The fishermen population engaged in Fisheries activities, including the whole family, was 1,60,96,975 people [2]. These workers are involved in many onboard and offboard physical labor tasks involving catching the fish, sorting, processing, storing, exporting, filling ice. Along with this, they are also exposed to different environmental risks while they work onboard the ship for 1–2 months. All these tasks involve many ergonomic risks factors such as repeated bending, lifting heavy loads, wet grips, repeated tasks, working in a cold environment for long hours. A previous research study in this area has found similar tasks involving the ergonomic risks resulting WRMSDs among the workers, where they have reported having pain in the lower back, shoulders, wrist, legs from tasks involving repeated movements of back, shoulder, elbow, wrist, legs and hand activities [3–12].

These processes in the fishing industry can be divided into four stages. Where stage 1 includes catching fish and storing, where the ship's crew members are involved in tasks such as throwing the net, pulling the net, unclogging the fish from the net, sorting the fish into different crates and storing them in ice. Stage 2 includes unloading the fishes on the deck and transporting the crates to the dockyard, where the ship crew members have to take out the fish from the storing unit and separate them from ice, unload on top of the deck, fill the fishes in the crates and transport them to the dockyard. Stage 3 includes transporting the crates to the trucks. Here the transport workers first weigh the crates and separate the fishes into two different crates and stack them (Fig. 1 a), then they are carried near the trucks (Fig. 1 b), where these crates are filled with ice (Fig. 1 c) before stacking them on the truck (Fig. 1 d). Stage 4 includes filling the storing unit of the ship with ice, where the ship crew members transport the crates filled with ice from the trucks and unload them in the storing unit, where they are again filled in different chambers.

Though many researches [3–10] have already been done on the onboard tasks, such as mentioned in stage 1 with findings showing the different ergonomic risks involved in the tasks involved, the later stages have been very less explored. A focused research study for the later stages is also essential to understand the WRMSD and their effects on the workers working in different stages of the fishing industry. As the stage 3 process where the workers have to carry and stack the crates from multiple ships and trucks, they are at high risk of developing MSDs. This study aims to find the WRMSDs and their effects on the workers involved in the stage 3 process and contribute towards effective interventions in the area for the journey towards the blue economy by improving the workers' health.

Fig. 1 Shows the different tasks involved in stage 3 process, (a) Task 1 where crates are weighed and separated in two different crates, (b) Women workers carrying the crates to the trucks, (c) filling the crates with ice, (d) Stacking the crates on the trucks

2 Materials and Methods

For the research study, a port in Karwar located at Baithkol, Karwar, Karnataka, was selected. Hills and coastal islands make the port a natural harbour, sheltered from the Arabian Sea. Along with an interview with the workers, a set of questionnaires was distributed among 38 workers.

Two questionnaires were developed where one questionnaire was based on a modified Nordic questionnaire which recorded the data regarding the MSDs developed in different body parts and also the frequency of the pain and discomfort, and the other questionnaire was based on a modified Dutch Musculoskeletal Questionnaire (DMQ), which recorded the data regarding the possible causes for the development of MSD among the workers involved in different tasks of stage 3 of the process such as and 1st task which include workers involved in weighing, separating the fishes into two separate crates, stacking and lifting the crates, the 2nd tasks involve female

workers who place the crates over their heads and transport them to the trucks, the 3rd task involves workers who unload the ice from the trucks and fills them in the crates, and the 4th task involves workers on the trucks who lift the crates and stack them over the trucks.

For the statistical analysis of the obtained questionnaire data, the frequencies of symptoms of the workers involved in the different tasks are compared to the entire population. Here Binomial test was used for the statistical analysis (Clopper and Pearson, 1934).

3 Results

3.1 Participants

Table 1 shows the demographic characteristics of the participants. Of all the participants, 10.52% were of < 20 age group, 36.84% were of 21–30 age group, 31.57% were of 31–40 age group, and 21% were of age group > 41. In addition, it is seen that 78.94% of the participants were of the male category and 21.05% of them were of the female category.

Of the 38 workers interviewed, 12 male workers were involved in the 1st task, 8 female workers were involved in the 2nd task, 10 male workers were involved in the 3rd task, and 8 male workers were involved in the 4th task. The mean age of all 38 workers was 32.8 years (SD ± 9 years). The mean age of the workers in task 1 was 29.4 years (SD ± 9.5 years), the mean age of the workers in task 2 was 33.3 years (SD ± 3.5 years), the mean age of the workers in task 3 was 33 years (SD ± 10 years), and the mean age of the workers in task 4 was 33.3 years (SD ± 9.9 years). The age distribution among workers from different tasks groups is shown in Table 2.

Table 1 Demographic characteristics of the participants

Parameters	Classification	N (%)
Age	<20	4 (10.52%)
	21–30	14 (36.84%)
	31–40	12 (31.57%)
	>41	8 (21%)
Gender	Male	30 (78.94)
	Female	8 (21.05)

Table 2 Age distribution among the participants involved in different tasks

Age (Years)	<20 (%)	21–30 (%)	31–40 (%)	>41 (%)	Mean (age)	SD
All workers	10.5	36.8	31.5	21.2	32.8	9
Workers in Task 1 (n = 10)	20	30	30	20	29.4	9.5
Workers in Task 2 (n = 06)	–	33.3	66.3	–	33.3	3.5
Workers in Task 3 (n = 12)	8.3	41.66	25	25	33	10
Workers in Task 4 (n = 10)	10	40	20	30	33.3	9.9

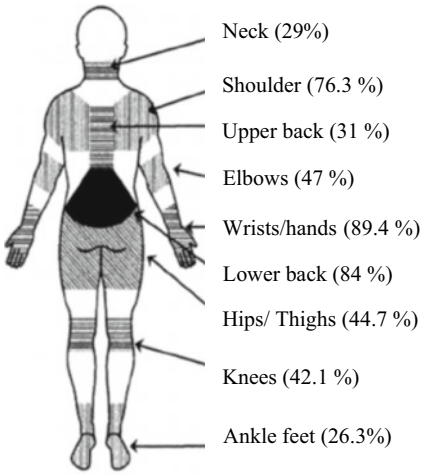

Fig. 2 Symptoms reported by the workers (n = 38)

3.2 Self-reported Musculoskeletal Symptoms

All 38 workers reported some discomfort in the body regions during the previous 12 months. The distribution of the symptoms in different body regions among all the workers is shown in Fig. 2. The age-wise distribution of these symptoms is given in Table 3. Here it was seen that the maximum percentages for symptoms were in the age group 31–40, where 63.9% of participants reported pain in the neck, 50% of them reported pain in ankle/feet, 47% in hips and thighs, 42.7% in knees, few percentages of participants also reported pain in other body regions such as shoulder, upper back, elbow, hands/wrist, lower back which was higher than those in other age groups. The lowest percentages for symptoms were seen among participants of age group < 20, where no one reported pain in the neck and feet and very few symptoms in other body regions.

Table 4 shows the Prevalence of these self-reported musculoskeletal disorders among the workers. Here it was seen that about 89.4% of the workers reported pain and discomfort in wrist/hand areas, 84% reported pain and discomfort in the lower back regions, and 76.3% reported pain and discomfort in shoulder regions, it was

Table 3 Musculoskeletal symptoms during the last 12 months as reported by the workers from different age groups

Body regions	Musculoskeletal symptoms during the last 12 months as reported by the workers from different age groups			
	<20 (%)	21–30 (%)	31–40 (%)	41> (%)
Neck	–	27.27	63.6	9
Shoulders	10.3	34.4	31	24
Upper back	16.6	25	33.3	25
Elbows	11.11	38.9	27.7	22.2
Wrist/hands	8.8	34.2	31.4	22.8
Lower back	12.5	34.3	28.1	25
Hips/thighs	5	17.6	47	29.4
Knees	12.5	31.25	42.75	12.5
Ankle feet	–	20	50	30

Table 4 Prevalence of self-reported musculoskeletal symptoms among the workers by body parts, work absenteeism and health care utilization

Body regions	YP	PV (%)	AW (%)
Neck	29	13	5
Shoulders	76.3	5	–
Upper back	31	–	–
Elbows	47	–	–
Wrist/ hands	89.4	13	5
Lower back	84	45	30
Hips/thighs	44.7	5	2
Knees	42.1	13	13
Ankle feet	26.3	5	5

YP 1-year prevalence; *PV* physician visits; *AW* absence from work

also seen that about 45% of the workers have reported visiting the physician and 30% of the workers have taken sick leave for problems related to the lower back.

3.3 Symptoms Related to Different Working Tasks Involved in Stage 3 Process

As seen in Table 5, of all the workers involved in task 1, 90% reported discomfort in hands and wrist, 80% reported discomfort in the lower back and 60% reported discomfort in shoulders, Whereas the highest discomfort percentage in Task 2 was seen in the neck, shoulders, wrist/hands, lower back, knees and ankle/feet. Here it was seen that the discomfort was significantly more in the neck ($p < 0.001$) and knees ($p <$

Table 5 Musculoskeletal symptoms during the last 12 months as reported by the workers involved in different tasks

Body regions	Musculoskeletal symptoms during the last 12 months as reported by the workers involved in different tasks			
	Task 1 (%)	Task 2 (%)	Task 3 (%)	Task 4 (%)
Neck	20	83.3 **	16.6	20
Shoulders	60	83.3	75	90
Upper back	50	16.6	33.3	20
Elbows	30	16.6	66.6	60
Wrist/ hands	90	83.3	91.66	90
Lower back	80	83.3	91.66	80
Hips/thighs	10	66.6	58.33	50
Knees	20	83.3 *	25	60
Ankle feet	0	83.3 **	16.6	30

* $p < 0.05$, ** $p < 0.01$

0.01) regions compared to the other tasks, the highest discomfort percentages in task 3 were in the wrist and lower back regions and in task 4 the workers reported highest discomfort percentages in shoulders wrist and lower back. Task 1, 3 and 4 gave a similar result as the overall workers reporting maximum discomfort percentages in shoulders, wrist/hand and lower back body regions, whereas task 2 which were performed by the female workers and did tasks involving them to lift the crates over their head and walk to the trucks reported highest discomfort percentages in neck, knees and ankle/feet along with the body regions shoulders, wrist and lower back as reported by the whole population.

3.4 Causes for Development of MSDs Based on Findings of DMQ

Following tasks with ergonomic risks involved were reported by the workers involved in different tasks

Task 1

- Lifting very heavy loads (more than 20 kg)
- Lifting in awkward posture
- Load above chest height
- Load is hard to hold
- Stand for prolonged time
- Bend and twist with trunk
- Bent posture for prolonged time

- Bend wrist
- Taxing physical work
- Working with cold
- Wet grip

Task 2

- Lifting very heavy loads (more than 20 kg)
- Lifting in awkward posture
- Carry very heavy loads (more than 20 kg)
- Prolonged walking with heavy loads
- Stand for prolonged time
- Hold arms above shoulder level
- Slipping during work
- Working with cold
- Taxing physical work
- Wet grip

Task 3

- Work with loads far from body
- Load above chest height
- Stand for prolonged time
- Stoop for prolonged time
- Bend and twist with trunk
- Repeated bending and twisting of trunk
- Make small movements with hands at high workplace
- Making same movements with trunk, arms and wrist
- Wet floor
- Working with cold

Task 4

- Lifting very heavy loads (more than 20 kg)
- Lifting in awkward posture
- Load above chest height
- Load is hard to hold
- Stand for prolonged time
- Bend and twist with trunk
- Bent posture for prolonged time
- Bend wrist
- Taxing physical work
- Working with cold
- Wet grip

4 Discussion

The study conducted over the research area has resulted in providing a base knowledge with data regarding the percentage occurrence of MSDs among the workers and the possible risks involved in all the tasks of the stage 3 process. Tasks 1, 2, 3 and 4 involved the following common ergonomic risks: Lifting very heavy loads, lifting in an awkward posture, bending and twisting of the trunk, taxing physical work, working with cold. The workers themselves considered these risks to be the leading cause for discomfort in the shoulders (76.3%), wrist/hands (89.4%) and lower back (84%). Similar findings have been seen in other researches done in different areas involving tasks with similar ergonomic risks [3, 5, 6, 10, 12, 13]. Task 2, which the women workers performed, reported maximum discomfort in the neck (83%), knees (83%) and feet (83%), along with discomfort in other body regions. They believed the possible causes to be the tasks involving: carrying heavy loads in awkward postures, prolonged standing while carrying the load, prolonged walking with heavy loads and holding arms above shoulder level, a similar study on women workers involved in similar tasks of carrying heavy loads on heads have shown similar findings where the workers reported pain and discomfort in neck, shoulder, wrist, knees and feet [13, 14]. In Task 3, the workers reported maximum discomfort in the wrist/hands (91.6%) and lower back (91.6%). They believed the possible causes to be tasks involving the following risks: Stoop for a prolonged time, repeated bending and twisting of the trunk, making movements with hands at the high workplace and working with ice. Many researches [15, 16] have found evidence of MSDs in the wrist/hand and lower back due to tasks involving similar ergonomic risk factors. In Task 4, the workers reported maximum discomfort in shoulders and wrist/hands and believed the possible causes to be a task involving the following risks: Lifting heavy load in awkward postures, loads above chest height, load difficult to hold, similar findings can be seen in the research done by Beek et al. [17], where the tasks involving similar risk have resulted in MSDs in shoulders, wrist/hands and lower back. It was also found that the workers of age < 20 reported less percentage musculoskeletal symptoms, whereas workers of other age groups showed an increase in the percentages of occurrence of MSD symptoms in most of the body regions, this result goes in line with the previous studies on age effects with MSDs where the symptoms percentage were seen to increase with age [18, 19].

The limitation of this study is that a complete detailed study on the different factors affecting the development of MSDs is needed for effective interventions in the area. The study done in this paper gives an overall view of the development of MSDs and possible risk factors in different tasks involved in the stage 3 process of live resource harvesting in fisheries.

5 Conclusion

The workers in the stage 3 process of live resource harvesting in fisheries at Karwar, Karnataka, involving loading of crates from the dockyard to the trucks for transportations, were found to be at high risk of development of pain and discomfort in shoulders, wrists/hands and lower back body regions. The significant risk factors for the development of MSDs were repeated lifting of heavy loads and prolonged carrying, work involving cold and wet grip, and repeated trunk bending and twisting motions. Thus, effective intervention is needed in the area for providing a good work-health balance among the workers.

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Identifying Ergonomic Issues and Re-designing of Mango Plucking Tool

Amol Patil and Amrita Bhattacharjee

Abstract Alphonso mangoes are harvested in Konkan region of Maharashtra and has significant impact on economy of local farmers. Alphonso mango harvesting is carried out by conventional methods which needs a huge labour effort. This study consists in-depth research of various methods carried out in Alphonso mango farm. Interviews, field research, photo and video ethnography, ergonomic study for body postures, task analysis has been done for understanding issues in conventional methods. Mango harvesting needs systematic management and well-trained labours to identify and sort mangoes according to its quality. Design intervention is necessary in conventional tools used for mango harvesting. According to research conducted for this case study, it is found that mango plucking is critical and most important stage in mango harvesting. However due to factors like aerial distance between mangoes and labour, difference in lightning conditions, change in size and shape of mangoes It is difficult for labour to identify which mangoes are ready for harvesting. Improper plucking affects ripening process of mangoes. Traditional mango plucking tool is made up of blade and bamboo or steel pipe. This plucking tool is re-designed with ergonomic considerations and use of modern technologies to identify harvesting stage of mangoes while plucking them. Automation and re-designing of this mango plucking tool will improve accuracy and saves time and efforts required by labour.

Keywords Ergonomics · Agriculture · Alphonso harvesting · Mango plucking · Automation · User experience

1 Introduction

Mango (*Mangifera indica* L.) belongs to family Anacardiaceae is universally accepted as the finest tropical fruit of the world and has been known as "King

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of the fruits" [1]. Alphonso mangoes of Ratnagiri and Sindhudurg district has received Geographical Indication (GI) [2] which enabled farmers for better opportunities in Indian market and export. Alphonso is a widely favoured and highly exported mango due to its distinctive and appealing flavour, low fiber-containing pulp, and high carotene content [3]. Although mango season is limited to summer, work on mango farms continues round the year. Various activities like plantation of new trees, cutting and care of old trees, fertilization, removal of grass and parasite plants, irrigation requires labor. Months from October to June are critical for mango harvesting. Spraying of pesticides, trimming of dried flowers, collection of raw mangoes, cleaning and sorting, packaging of mangoes are important tasks during these months.

The research and observations were carried out through field visit and ethnographic study. Interviews were the eye opener to get knowledge about ripening and quality of mangoes. Various harvesting methods were assessed to understand pain points of stakeholders like farmers, labors and market retailers.

2 Process

Double diamond process is followed to understand shortcomings in traditional mango farming. Study of double diamond process is essential to enhance user experience. This process is divided in to four stages namely—Empathize, Define, Ideate, and Prototype (Fig. 1 and Table 1).

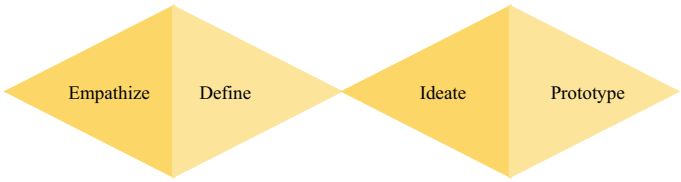

Fig. 1 Schematic representation of double diamond process

Table 1 Methodologies used in the research

Empathize	Define	Ideate	Prototype
A day in life of farmer	Card sorting	Sketching	Digital rendering
Ethnography	Persona	3D modelling	
Interview	Journey mapping		

2.1 A day in Life of Farmer

This process helped us to understand which various activities are carried by farmers in their daily life. It gave us insights for pain points of farmers like mangoes are not visible in dense branches, need to climb on tree, maintaining balance and handling mango plucker during climb, transferring mangoes from trees to storage space etc. These pain points are essential for design consideration of tools.

2.2 Ethnography

Ethnographic research is useful to get qualitative analysis regarding issues. Methods that are used in ethnographic fieldwork are observing, talking, and studying artifacts [4]. We conducted photo and video ethnographic research. It helped us to understand activities carried out by farmers and their corresponding body postures. During ethnographic research we conducted interviews of farmers and labors. Figure 2 will help to identify various body postures also issues related to handling of plucker.

From direct observation we noticed that to pluck mangoes labor needs to jolt stem using plucker. To pluck mangoes from top of tree labor has to stretch his upper arms beyond 90° and wrists are twisted thus during jolting stem results in impacting effect on arms and wrist. As blade attached to plucker gets old jolting force needs more.

In Fig. 2 we can observe that labors have to climb on tree to reach at top and to pluck mangoes. Ripening stage of mango is decided based on its color, notch at stem

Fig. 2 Photo ethnography during mango plucking process (**a**, **b** respectively)

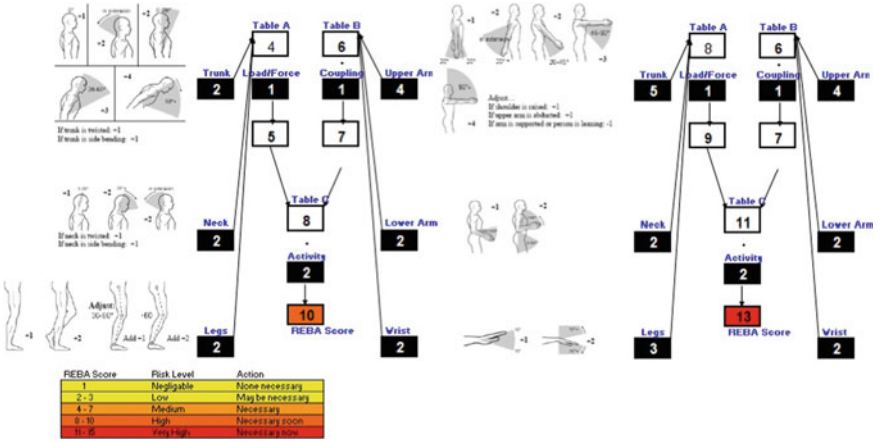

Fig. 3 REBA analysis for Fig. 2a, b respectively

and its shape. Aerial distance between labor and mangoes is more than 6 feet and thus it is difficult for labors to identify which mangoes are ready for ripening and thus it impacts collection of mango. Climbing on tree is risky as labors may have to climb at 15–25 ft above from ground surface. At this level it is difficult for labor to maintain balance as well as to handle mango plucker. Body postures during such process leads to Musculoskeletal Disorders.

Postural analysis is a useful for evaluating labor activities [5]. To understand criticality of body postures we used Rapid Entire Body Assessment (REBA) tool. Body postures are analyzed by drawing line diagram for neck, trunk, legs, upper arm, lower arm and wrist. Their deflections from normal positions are measured to mark score on basis of REBA worksheet.

Figure 3 shows results of REBA analysis done for body postures in Fig. 2. Here we can see that REBA score is 10 for plucking position from ground and 13 for plucking position during climbing on tree. These scores lies in between High and Very High Risk level which suggests that action to change and improve body postures is necessary now.

Interview Insights

2.3 Mango Agronomy

Ripening stages of Alphonso mangoes are identified based on the color, shape and notch formed at stem. Mangoes are plucked from a tree when its color changes from dark green to light green but it can vary according to temp and exposure of sunlight. More exposure of sunlight results in change in color to light green or yellow but it can be unripen.

We have taken reference from Booklet of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli to understand changes in mango according to its harvesting stages. In Fig. 4 we can see how color changes from dark green to light green and shape of mango takes round shape (Fig. 5).

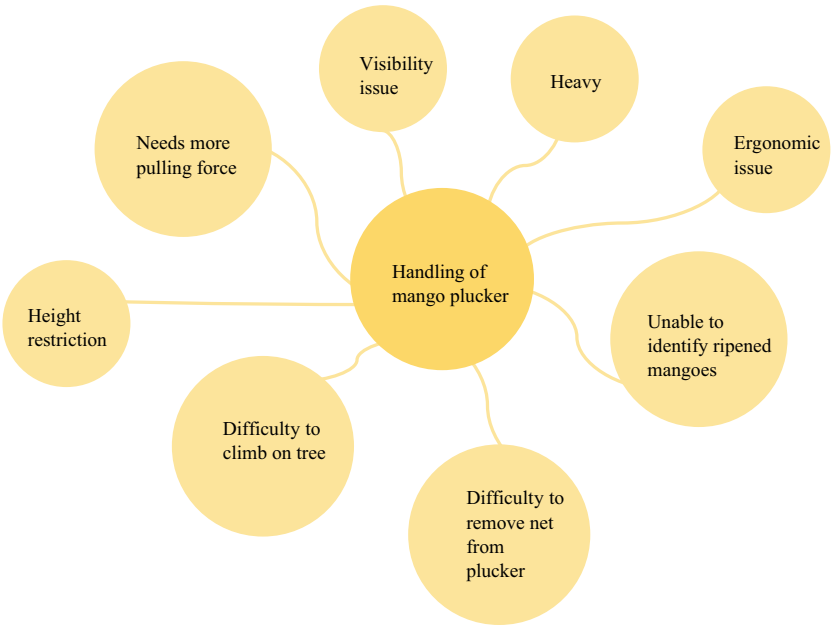

Fig. 4 Interview insights schematic representation

75% ready for harvesting

Dark green fruit forming right angle at stem

85% ready for harvesting

Light green fruit forming slight depth at stem and raises sides upward.

100% ready for harvesting

Light green/ light yellow fruit forming more depth at stem around 10-15 mm and raises sides upward.

Fig. 5 Harvesting stages of mango

2.4 Design Considerations

Various factors were analyzed based on desk research, ethnographic study, interview insights and market study. We used card sorting method to priorities this insights.

- Light-weight product
- Increase visibility while plucking mango will reduce efforts to climb on tree
- Assistance for selection of mango
- Easy penetration of plucker across branches
- Easy removal of net

Concept

Figure 6 shows final design concept of mango plucker. Elevated blade position helps to cut stem at 80 mm distance from mango thus avoids spillage of sap (liquid from step) on mango. Camera and Wi-Fi module is used to capture live images. It will reduce strain on labors eyes to search for right mangoes. Hooks are provided for easy removal of net. Batteries and on-off plug will be kept inside tubular structure.

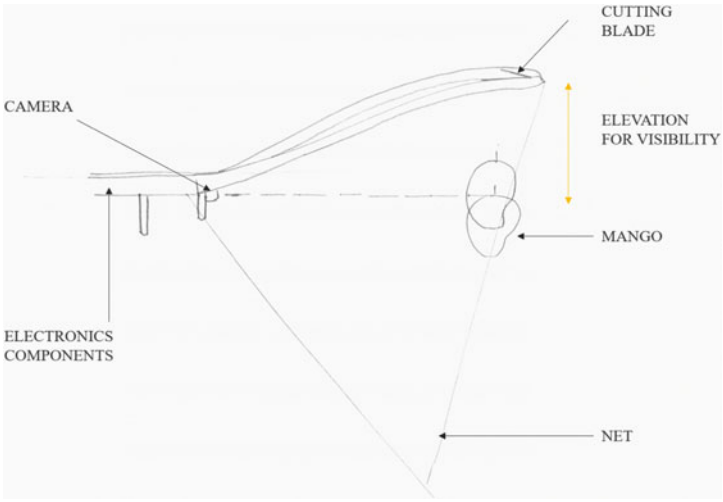

Fig. 6 Final design concept of mango plucker

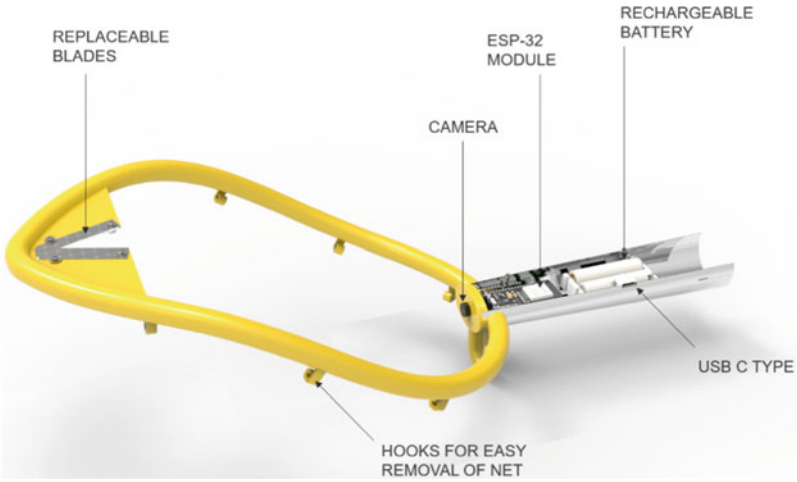

Fig. 7 Technical details of product

3 Solution

3.1 Technical Requirements

Figure 7 shows electronic components and their placement in this product.

The ESP32-CAM development board is a tiny, low-cost ESP32-based development board with an integrated camera. It's an excellent choice for Internet of Things

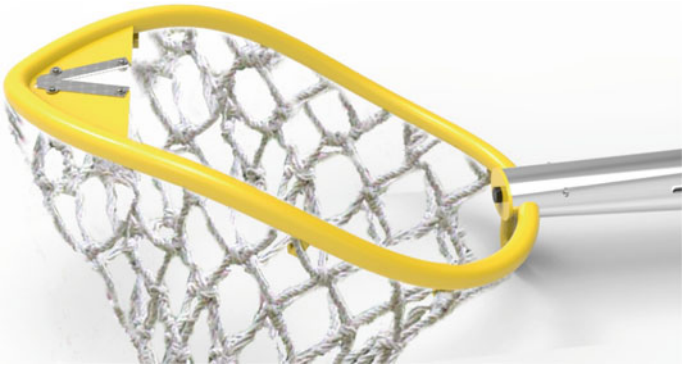

Fig. 8 Mango plucker

Fig. 9 Mango plucker with handling pipe

(IoT) applications and do-it-yourself projects [6]. It have integrated Wi-Fi and Bluetooth. In this project we are using this device to only transmit video signal through wi-fi. Power supply of 3 V will be provided at pin GND and 3V3. Rechargeable batteries are used as power source. C-type port is used to charge batteries.

Camera sensor is used to capture live image of mangoes in plucker. This image will be shared on mobile with wifi module. AI filters in mobile app will assist labor with harvesting stage of mango. Thus labor can easily pluck mango from any part of tree. Elevated surface of blade provides better visibility of stem area for camera also it enables labor to cut stem with length of 10–12 cm. Longer length of stem is required to avoid damage of mango.

Convergent shape of mango plucker enables easy penetration across branches. Net is attached using hooks which enables labor to replace it easily.

Handle of mango plucker is designed based on anthropometric data.

Prototype renders

Figure 8 shows view of cutting blade and net area. Here we can see that elevated surface enables better visibility of stem area of mango in camera (Fig. 9).

3.2 User Interface

Figure 10 shows various screens used for mango plucking assistive app. Figure 10a is a Home Page. Live images captured by camera will be shared to mobile with wi-fi module. Here though mangoes are at distance, it will enable labor to see exact color and notch formation at stem on mobile app. Smart plucker is assistive app which will analyze live images with pre-recorded data based on color and notch formation at stem. In Fig. 10b, c we can see that blue outline is generated with pre-recorded data. This outline is compared with live outline shown by red color. Analysis will be shown to labor with easy notifications like thumbs-up or thumbs-down. This information will help to identify whether mango is ready for harvesting or not.

One labor can handle mango plucker whereas other one will handle mobile. This coordination will help both to pluck right mangoes. This process will save time to identify harvesting stages of mangoes as well as risk and efforts to climb on tree.

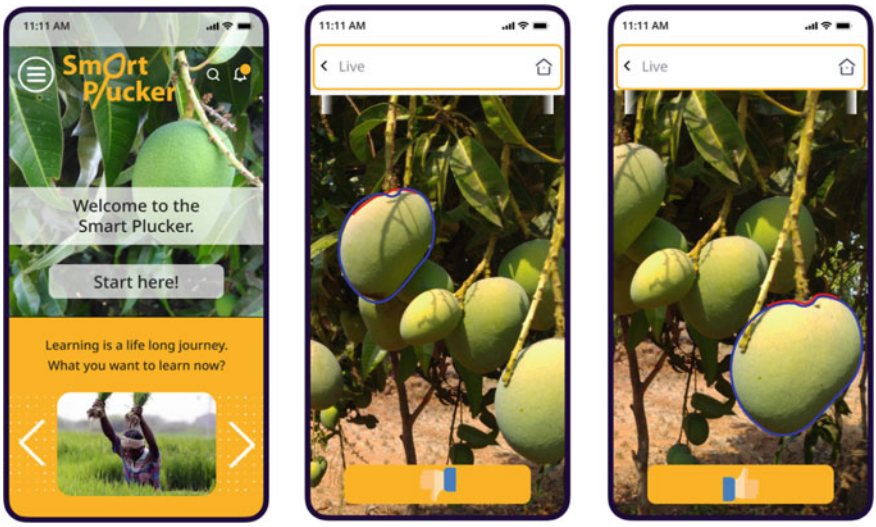

Fig. 10 UI screens of mango plucking assistive app

3.3 User Interaction

In traditional mango plucker as blade is in inline of pipe, it does not allow labor to see distance between cutting position of stem and mango. In this design, labor handling mango plucker itself can have better visibility while plucking of mangoes. As shown in Fig. 8 elevated surface helps labor to see distance between blade and mango, also camera will provide image of mango. Labor holding mobile can see live image of mango in plucker and will get imagery response whether mango is ready for plucking or not. Labor can also analyze by himself as stem notch, color and roundness of mango is visible in image, thus reduces dependency for climbing on tree to check for correct size of mango. He can guide primary labor to select that mango or not thus it will help to identify more precise ripening stage of mangoes.

Elevated surface gives ample space for mangoes and stem thus there is very less chance that stem will stuck in between blades which reduces jolting force during mango plucking.

4 Conclusion

Nowadays many farmers are facing challenges to get knowledgeable and reliant labors. This re-designed mango plucker is designed with considerations ergonomic and technical issues faced by labors. Elevated design will enable better visibility to labors also assistive app will help to identify quality and stages of mango harvesting. This process is less time consuming and safe as compared to traditional process. Re-designed mango plucker will enable labor to pluck mangoes from ground itself thus risk of climbing on tree is reduced.

Slender design of mango plucker enables easy penetration across the branches. V-shaped blades will enable to cut stem with least pulling force.

Electronic components used are cheap and easily available. Re-designed mango plucker will cost around 1000 Rs. This is one time investment and thus reduces dependency of skilled labor.

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Learning Indian Classical Dance Forms with the Help of Augmented Reality (AR) Application

Sudakshina Choudhury and Anirban Chowdhury

Abstract Indian Classical Dance forms have always been classy and a very hard dance form to learn and understand. A small research was done to understand as to how young dancers, learners think about the collaboration learning of classical dance. Most of the students and learners are not being guided properly in most random dance learning institutes. Indian Classical Dances have dynamic moves and positions that are often not understood by many learners and dancers even after attending physical workshops as the trainers and instructors are not very interested in demonstrating it again and again for students. A solution has also been proposed to the problem of young dancers and learners across the world face while trying to learn or reach out trainers or experts. To maintain the beauty and divinity of the dance styles, a novel AR based classical dance app has been ideated. This technology-based solution has made possible a lot of things such as making culture, tradition famous and known. If people used this solution wisely, it can promote as beautiful and dynamic as classical dances on a global platform and also help in reaching the dance forms in reaching greater heights.

Keywords Augmented reality · Dance · Learning · Usability · User experience

1 Introduction

1.1 Indian Classical Dance

Indian classical dance or 'Shastriya Devesh' is a term particularly used for Indian traditional dance styles that can be deeply rooted to the history of Indian tradition and can be traced to back to a very long history of the origin of Indian Classical Dances [1].

There are basically 8 recognized different Indian Classical Dance forms. The list of the dance forms are as follows:

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(1) Bharatnatyam (2) Kathak (3) Kuchipudi (4) Odissi (5) Kathakali (6) Sattriya (7) Manipuri (8) Mohiniyattam [1].

Indian Classical Dance forms were never easy to learn. The dynamic moves and tough steps make it difficult for a lot of students to learn in one go. Many students also do not get a chance to actually make it to a good institution.

Technology has a lot of potential to make tough things easy and also contribute highly to help students learn and explore various fields such as dance forms, art, music and other educational sectors [1]. Emotions/affect have a direct correlation with the mental state, as well as intention of a person, based on which his/her present and future states can be understood and predicted [1].

Augmented Reality or AR is an effective way to create interest among students and also general public for simple things and activities in day to day lives of common people. AR has the potential to make art forms reach a wider platform and also make it easy to learn and understand.

1.2 Augmented Reality and Dance

AR is used by a lot of mobile applications which aims to teach dance and is effective for students who cannot or are not interested in learning dance by attending physical classes or workshops. There are applications available already for different Western Dance forms. AR is used to make dance learning easier and more interesting [1]. Interface style and perceived ease of use had a weak influence on perceived enjoyment [2].

The AR might be very helpful when learning dynamic moves of Dance and expression as it helps artists to analyze how do they look like while performing as well as while learning. AR and Indian Classical Dance forms will be a very new approach to make the dance forms more famous and easier to learn. AR will be very helpful to people learning Classical Dances as it will help artists from all over the world to learn something new and different [2]. Sensors can be very useful while making invisible aspects of the task visible to apprentices and also by allowing them to achieve a better understanding of the things being learnt [3]. Also, in addition recorded expert performance data can be used to train apprentices, but it can also assist experts by enabling them to quickly create training materials while demonstrating [3]. Apprentices have the opportunity to replay the expert's demonstration in a much richer manner while actually doing the task or, when needed, to learn from the demonstration [3].

2 Literature Review

In the past many years, a lot of choreographers have put on their focuses on learning dance by the implementation of Computer Technologies such as AR (Augmented Reality) [4–9]. Computer Technology is helping dancers as well as choreographers to

discover areas that were unknown. Computer technology helps in assessing movements as well as provides scope to discover to learn and know about other dance resources and make it available. Augmented reality is an emerging technology that utilizes mobile, context-aware devices (e.g., smartphones, tablets) that enable participants, learners, artists to interact with digital information embedded within the physical environment to get a wholesome and impactful performance [10, 11].

People who are passionate about culture, art and dance usually rely on institutes dance teachers who sometimes do not really pay much attention. This is the major factor that pushes a lot of artists to pursue self-learn which is a growing trend that can be noticed. Many people come together on social media and promote challenges to boost up confidence among the others which leads to people learning thing themselves. AR brings out an effective solution to learning complex movements which cannot be learnt easily.

2.1 Visualization in Immersive Media

The significant benefits over existing techniques are—the ability to use the Head Mounted Display (HMD) sensor, hands could be used for gesture based inputs, for an improvised head and positional tracking and automatic peer to peer network building for exchanging messages between phones [12]. The mobile AR prototype app was built to assist the learning process of folk dances. This app was based on AR Core platform because it has the feature of motion tracking, understanding of the environment and estimation of light. The AR application can be used in both ways—portrait and landscape mode and both consists of showcase and learning mode [2]. In showcase mode, users can watch the whole dance without any interaction before they start learning [2]. The concept is to familiarize users to the dance so they can see what they are expected to learn and reproduce [2]. After this step they can approach learning mode [2].

2.2 Self-learning

People who are passionate about culture, art and dance usually rely on institutes dance teachers who sometimes do not really pay much attention. This is the major factor that pushes a lot of artists to pursue self-learn which is a growing trend that can be noticed. Many people come together on social media and promote challenges to boost up confidence among the others which leads to people learning thing themselves. AR brings out an effective solution to learning complex movements which cannot be learnt easily.

Mobile devices such as smartphones, tablet, and other wearable devices are now widely adapted by users and these new technologies are constantly consumed. Pachler

and colleagues (2010) emphasised that learning on mobile devices is a quickly developing field of education technology research and practice [3]. Hence, these technologies promote the self-learning and adopted a new learning behaviour for new generation of learners.

2.3 Major Drawbacks of Offline Learning

Major drawbacks of online websites and physical classes is that a very few artists actually get the chance to learn an art form with utmost excitement. It is also quite difficult to actually travel or settle down in a particular place is demanded by most of the reputed institutes here in India. The involvement of technology not only helps in breaking the barriers of travelling and settling down but also enhances the learning of each individual.

Educationists are authoritative for training apprentices; therefore, learning from experts is difficult. Experts might frequently fight to explicate and/or verbalize their knowledge or simply ignore vital details due to incorporation of their skills, which may make it more complex for learners to learn from those experts. Furthermore, the lack of experts to support learners in one-to-one settings during exercises restricts the development of learners [1].

2.4 Fun Based Dance Learning App

The use of AR may increase motivation for students and contribute to improved academic achievement [6]. Computer Technology and motion sensing technologies have enabled its users to physically interact with the digital environment in various ways. The combinations of traditional art forms and advanced techniques have made the involvement of technologies such as AR to actually create a big and effective impact on its users. The involvement of AR to learn the complex gestures and movements of Indian Classical Dances is likely to create a global impact since the popularity of Indian Dance forms and culture is remarkable [4]. Augmented Reality (AR) Mobile Apps are a very usefull technology for Cultural Heritage Communication additional to knowing and learning it [8].

The combination of Indian Classical Dances and AR will not only have an impact on the Western learners but will greatly help people of India who are not able to avail the basic learning and instructions from authentic and reputed dance Institutes.

AR has had a great impact on the educational sector where it has made easy the learning of various educational topics, helped artists and other people at work to discover something very new and inspiring. The success of new technology promises its users that a lot of things can be kept going and preserved with the help OF AR. Fun filled AR based dance learning is a positive sign towards the development and making a larger picture for the Indian Classical Dance forms. Fun filled learning not

only engages the user but also promises that even though an art form seems to be difficult to learn it can be easily overcome by just the help and involvement of the growing computer technologies such AR [4].

2.5 Public Interest Statement

Dance learning by prerecorded videos, or online videos often times lead to improper training. Lack of guidance and atmosphere also gradually leads to dancers losing interest in learning a new and different art form. To keep the interest, dancers need be kept engaged for them to learn it with utmost excitement and a sense of pleasure and satisfaction [4]. Motivational factors such as attention and satisfaction in an augmented-reality-based learning environment were better recorded when compared to to those obtained in a slides-based learning environment [7].

AR can be considered as a cognitive tool and is also a pedagogical approach [9]. Modern AR systems can communicate with various sensors in real time. Sensor-based AR helps in providing better guidance and feedback when experts are not available. Sensor-based AR environments also provide a rich multimodal and multi-sensory medium to learn efficiently mainly focusing on self-learn and not relying on expert guidance at any point of time [4]. The relationship between augmented reality, mobile learning, gamification and non-formal education methods provide a great potential [13–15].

Sensors have great capacity to notice minute details that are required to give a better learning experience. Sensors also have the ability to clone any model which in turn helps in getting great engagement and fun. The sensors also have the ability to copy the exact environment in which a performer performs and also is able to tell if something is wrong instantly. Involvement of sensors in areas such as the Indian Classical Dances where every movement needs to analyzed and criticised. The dynamic movements of the dancers can be easily traced by the dancers for a better view and understanding of the art form. In addition, the traditional video platform is less interactive and doesn't give Realtime feedback to dance gestures, whether its correct or not.

2.6 Aims and Objectives

1. Aim of this collaboration of AR and Indian Classical Dance forms is to make the art form reach bigger platforms.
2. To make learning of the Classical Dances much easier and making its learning as per the user's choice
3. To make artists learn about Indian culture by teaching dance forms online without the need of any physical dance classes.
4. To enhance the learning of the difficult steps of dance forms.

3 Method

Learning a dance style with proper guidance is extremely important which is kind of missing in most random institutes. To enhance the learning and overall experience, a unique interaction style is introduced where the app will be using sensors to give a better and real experience.

3.1 User Requirement Analysis

3.1.1 User Interview

A structured User Interview has been conducted using a set of situational questions regarding Indian classical dance learning tool. A set of questions was prepared to get an idea how people are reacting towards this idea and how they feel about it. A total of 15 Indian classical dance learners were interviewed (5 females and 10 Males, Age range = 17–23 years).

3.2 AR Based Mobile Application Design

Developing an AR based application that particularly focuses on the Indian Classical Dances can help solve a lot of major problems that common people, artists and dancers face. If the product or solution works well and if it implements the technology, it will gain popularity and will gather the attention of various artists as well as collaborate with elite institutes. Since, people are so much into technology nowadays and when most of the things are carried out online, it will be a very new approach towards learning something as beautiful as the Indian Classical Dance forms.

The proposed app concept is described as follows:

- An app-based dance learning technique which will focus on Indian Classical Dance styles and will include classical music as well to enhance the overall learning experience.
- The application will help create a 3D clone of the user using the LiDar sensor, which will help the user to understand the dynamic movements of the classical dance forms.
- The application will also use other sensors such as the gyroscope, accelerometer and magnetometer.
- The application will have additional features such as addition of classical music for each level of the ongoing dance.
- An AR based dance learning application that will give a real time experience to the users so that the interaction remains unique and an experience that will attract other dancers as well.

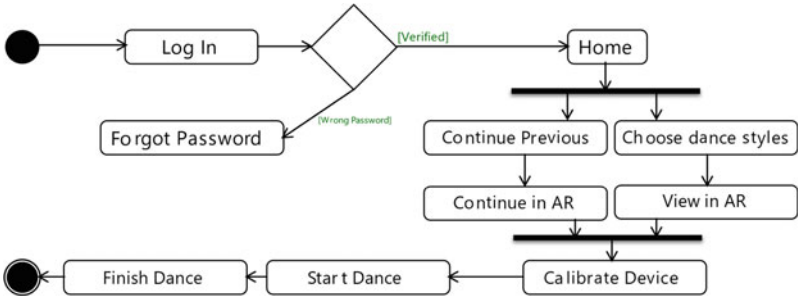

Fig. 1 The activity diagram for proposed AR based mobile app

- The task flow of the app is presented through activity diagram in Fig. 1.
- The user interface was designed and a prototype was developed based on above concepts (see Fig. 2).

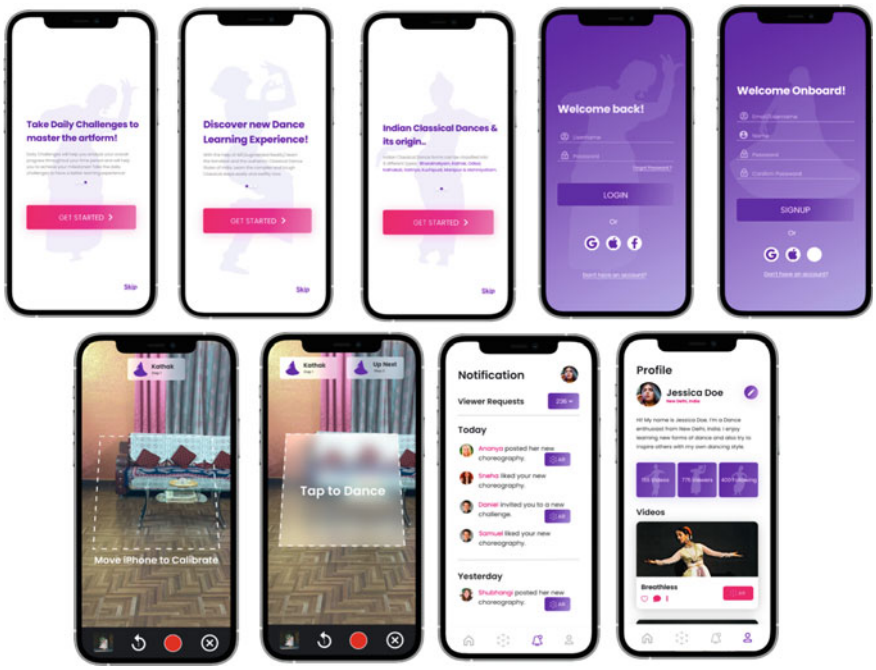

Fig. 2 User interface for AR based dance-learning mobile app

3.3 Cognitive Walkthrough

A total of 2 tasks were carried out by 5 expert users. The expert users were sent a video prototype which they analyzed and handed the report.

3.3.1 Background Summary

The final prototype was made on Adobe XD. The whole prototype was screen recorded and sent to 5 expert users who have reported about the usability of the application.

Tasks Performed

Task 1: Learn a particular step of a particular dance form by using the AR room.

Task 2: Take up a challenge and learn a step from that choreography.

Disclaimers

A walkthrough was provided to the users to make them understand how to proceed with the application and how the app will be teaching them dance with the help of AR. The users were told about the LiDar sensor and how it will help in making a 3D clone of the user and how it will teach them the dance steps.

3.3.2 Goals

- To understand if the dance learning was simple and easy in the application.
- To understand if the application is easy to understand and not much confusion is arising while operating the app.
- To understand if the app is giving a wholesome and different experience altogether to the Users.

4 Results and Discussions

The results from user survey and the cognitive walkthrough with 5 expert users are written in details down below.

4.1 What User Says About the Requirements?

Dancers/users will be needing a way that helps them to actually see themselves while they try to learn the dance steps. Users need teaching and training in a way that they are able to learn the steps and dance again and again without offending the teacher. Dancers and users will also need a way to learn Indian Classical Dance forms without actually attending any physical workshops. Students and learners from other parts of the world can also then participate and learn the artforms in their comfort. A social and common platform for all Classical Dance learners is a need for most of the learners because a lot of people prefer to learn classical dances from reputed institutes rather than any random dance learning institutes. This will stimulate the learners to connect with other artists on a common platform and will be able to have a better experience altogether.

The important responses from these people were noted and presented below-

1. The dancers interviewed had a common complain of not having an overall learning of the culture and had issues with learning it correctly since physical classes had particular time and did not focus on the overall learning.
2. Newly learning students find it difficult to cope with the fast steps and proper coordination.
3. Classical dancers emphasized about the learning of hand mudras and gestures.
4. Facial expressions are an important part for any dance and this needs to be taught properly.
5. Essence of dance should be always present while learning and it should not feel like users or students are doing the steps just for the sake of doing it.
6. Learning dance online has always been a little complicated since most of the students were not able to get feedbacks and were not able to analyze themselves.
7. Many students also look forward to learn classical dance from reputed dance institutes rather than any random dance classes.
8. Most dancers feel that learning dance online will not be that difficult if it is able to get the essence and beauty of the dance form and is able to teach the dynamic moves of each classical dance form. Dancers say that it will be great if they are able to look at themselves while they try to learn the steps.

4.2 Expert Suggestions After Prototype Walkthrough (Previous Versus New Design)

Experts have highlighted that the designed AR app is a platform to practice dance and share the dance videos with other learners across the globe, so that it encourages and helps others to learn better and improve. Experts were pretty much satisfied with the concept and idea of learning dance with the help of AR. They also said that users might want a set of predefined instructions before the app is being used. Experts have said that the application is easy to understand and that they did not find anything that

was very confusing or hard to understand. Some of the users look forward to use this app in the near future if it is launched.

The AR screens can be given some more details after finalizing some additional features. The user interface of the AR screens can be made more user friendly. Also, later the app can incorporate features from machine learning and Artificial Intelligence. The app can add other dance styles also to broaden its audience later on. The aesthetic beauty of the AR screens can be made better and certain colour combinations can be changed from a monotonous color palette to a more darker color scheme (see Figs. 3 and 4 to compare initial and final design respectively).

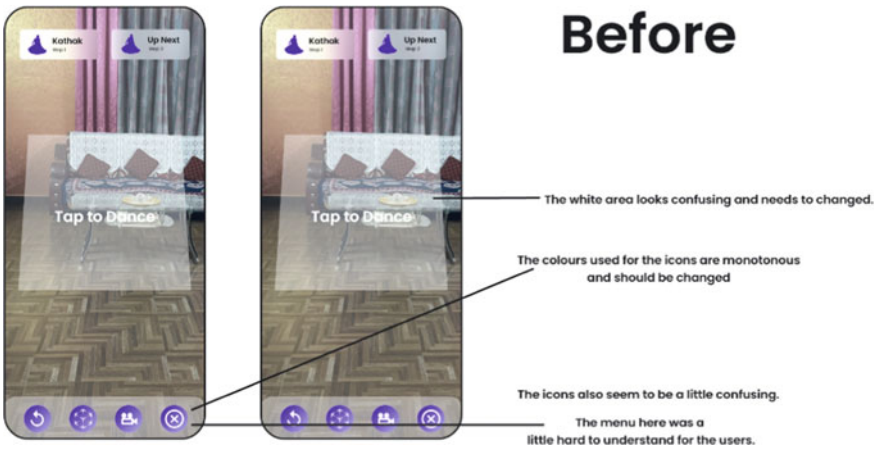

Fig. 3 Initially proposed design of AR based dance-learning mobile app

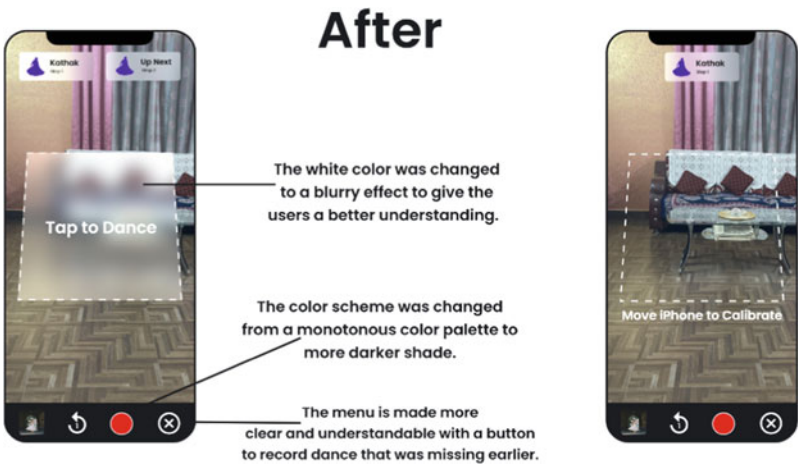

Fig. 4 Final design of AR based dance-learning mobile app

5 Conclusion

The advantage of AR in educational sector includes prospect to visualize digital information, observation of the finer and minute details of topics and also to get a better understanding of various different aspects of various fields of studies [3]. The positive impact of Augmented Reality (AR) applications has been mentioned by many researchers in the context of primary, secondary and higher education. The AR applications can help students in terms of learning gains, motivation, collaborative learning, interactive learning, enjoyment etc. [14]. Similarly, the design application presents the combination of Classical Dances and AR based technology might inspire a large group of audience and artists who are hunting for something new as well as want to stick with the fun and creative twist to the activities.

Currently, the app does not incorporate AI as of now, but the AI might help in getting correct feedback for the users. The app also has limitations with the styles of dance offered. This app is not a coded prototype and is still a medium fidelity prototype. The app can be coded and launched in the future which might have a big impact on the dancer's community. The app can inculcate finer details and can be made more visually appealing. Some extra features such as instant feedback session after dance can be added to make the application more easier to use and understand. The virtual reality (VR) apps are also having potential application in learning dance gestures which can be explored in near future.

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Design, Development and Performance Evaluation of Foot Operated Elephant Apple Core Cutter

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Abstract Elephant apple has been found to contain various medicinal and pharmacological properties but due to limited processing technique its utilization is limited. This study was conducted with the objective of developing a mechanized foot operated elephant apple core cutter with an ergonomic design to reduce stress and require minimum amount of strain. The cutter was designed and developed by considering the physical properties of elephant apple where the core cutting is accomplished by mechanical coring of the elephant apple placed in a horizontal plane. The cutter consists of four unit's viz. frame, cutting base, coring unit, and pressing unit. The cutting base and coring unit contacting elephant apple are made of food-grade stainless steel. Mechanized cutter performance has been evaluated in terms of capacity, machine efficiency, and loss percentage, etc. and was compared to that of the conventional cutting method. The average cutting capacity of mechanized core cutter (MCC) was about 115–130 kg/h compared to that of conventional method with 13–17 kg/h. The mechanized cutter also offered higher sepal yield (85.55 ± 1.81%) compared to the conventional method (64.23 ± 2.43%) indicating the overall performance of the mechanized cutter to be far better than conventional method in terms of quality, quantity and stress involved. This cutter proved to be ergonomically sound, less likely to cause muscle strain, and consistent with the users' desired position.

Keywords Ergonomic · Musculoskeletal disorder · Mechanized core cutter (MCC) · Cutter efficiency

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1 Introduction

The North Eastern Region of India is rich in many indigenous plants produce but due to limited processing methods utilization of most of the plants produce is restricted. Elephant apple (*Dillenia indica*) (Fig. 1) belonging to the family Dilleniaceae is one of the underused agricultural fruit crops that is mostly found in sub-Himalayan region between Garhwal and Assam, Arunachal Pradesh, Tripura, Manipur, West Bengal, Bihar, and Orissa along with Central and Southern India; in forests at low and medium altitudes in Nepal, Bangladesh, and Sri Lanka [1]. Elephant apple fruit also known as Ou tenga in Assam and Chalta in West Bengal have been found to possess extensive medicinal value [2] including antioxidant [3, 4], anti-microbial [5], anti-cancer [6], anti-diarrhoeal [7], anti-mutagenic [5], and immunostimulating [8] activities, but it has long been regarded as an underutilized fruit due to the time and effort required for post-harvest processing. Since most of the processing techniques used are outdated, the losses during peak season are large. So, there is a need to develop appropriate technology for processing of elephant apple fruit. The fruits of elephant apple are globose with accrescent calyx, 12.5–15 cm (4.9–5.9 in) in diameter, and have thick fleshy sepals sticking closely to the fruit where 5 sepals are fitted closely throughout numerous seeds containing glutinous juices [9].

Cutting of an elephant apple fruit is a tedious process and thus it is not used commercially on a large scale. The fruit is hard and thickly covered, with five tightly fitting imbricate sepals that must be removed one at a time, adding to the time, effort, and loss. Since long time elephant apple is manually cut by traditional tool as shown in Fig. 2 which takes around 100–113 s depending on the skills of a person. The existing conventional tool, as well as its poor design, contributes to the development of numerous work-related musculoskeletal disorders (MSDs). Squatting or sitting on the floor with folded knees is the most common way to cut fruit. When squatting, the

Fig. 1 Elephant apple (*Dillenia indica*)

Fig. 2 Conventional method of cutting

body is folded into three sections, with the buttock and thigh remaining unsupported which may lead to some musculoskeletal discomfort. Using the conventional tool, meanwhile, may result in a misalignment of the body's orientation. While sitting and squatting, the conventional tool tends to cause a variety of discomforts, including back pain [10]. As reported by the National Institute for Occupational Safety and Health (NIOSH), crouching or kneeling down, squatting, stooping, and lifting involving non-neutral trunk postures are uncomfortable postures that can contribute to lower back problems [11]. Furthermore, cutting the fruit traditionally with a sharp-edged knife poses a risk of injury to the operator and inadequately cutting of the fruit can also lead to issues during other stages of production, such as during removal of core from the fruit. Thus, it is necessary to cut the fruit properly so that the core can be removed with minimal loss. Since the conventional cutting method is slow and time-consuming, a person's ability to process a large number of fruits is limited [1]. Considering the problems involved in using traditional tool for cutting an elephant apple, a core cutter is engineered keeping in view the ergonomic principles and evaluated for its performance in terms of cutter capacity and sepal yield.

2 Materials and Methods

The first step in the development of machine will be to obtain certain information about the specific samples to be processed. This basically entails the assessment of the materials, different parts and components to be used for fabrication depending on the physical properties of the samples, since this is extremely important in determining the potential of the machines to process the samples conveniently. The second step

involves study of operation of the cutter based on the technical arrangement ergonomically for transmitting force from the foot pedal/lever to push the fruit holder upwards, connected through three shafts. For the present study the following methodology and work plan is executed as discussed below.

Elephant apple fruits were collected from the Kokrajhar district (Assam, India) and stored under stable conditions for at least 4 h at a temperature of 25–30 °C and a humidity of 50–55% before the trials.

2.1 Fabrication

The procurement of material plays a significant role in the manufacturing of machinery in order to fulfil standards of operation and hygienic standards of the finished product. Since some parts of the foot operated MCC can come into direct contact with the elephant apple fruit, they were made of stainless steel (SS), whereas parts involved in mechanical operation were made of mild steel (MS). Since elephant apple is acidic, they can react with metal or MS, causing oxidation leading to rusting and migration of dangerous materials into produce. As a result, the core cutter, fruit holder, core collector and sepal's collector are made of stainless steel.

The components used throughout the fabrication of the foot operated MCC are shown in Table 1, and the dimensions of the cutter are shown in Table 2. The fabrica-

Table 1 Materials selected for fabrication of foot operated MCC

S. No.	Particulars	Material
1	Pipe (50 × 60 mm)	Stainless steel
2	Square pipe (8 Ft.)	MS
3	Flat bar (25 × 5 mm)	MS
4	Foot press lever	MS
5	Collecting box	Stainless steel
6	Nut bolt	MS
7	Colour	N/A

Table 2 Dimensions of foot operated MCC

S. No.	Component of cutter	Material type	Dimensions
1	Frame	Mild steel pipe	4.0 Ft
2	Fruit holder	Stainless steel	80 mm
3	Cutter die	Stainless steel pipe	40, 45, and 50 mm
4	Foot press lever	Mild steel pipe	465 mm
5	Shafts	Mild steel pipe	270, 284, and 240 mm

tion process involved labelling, carving, welding, grinding, finishing, and painting, among other aspects. Both lathe and grinding tools were used to sharpen the cutter die, electric arc was used to weld the tee and corner joints, and angle grinder was used to complete the joint finishing.

2.2 Parts of the Foot Operated MCC

The different parts of foot operated MCC are supporting frame, core cutter, fruit holder, fruit core and sepal collecting boxes, connecting links, extension spring, and foot press lever as shown in Fig. 3. In the sections below, each important part (core cutter, fruit holder, and foot press lever) has been discussed. The layout was developed using Autodesk Fusion 360 software.

Core cutter

The core cutter is the most important part of MCC. It is designed to separate the elephant apple core which is held together by imbricate sepals. The core from the elephant apple is removed using the core cutter, which is a hollow cylinder with sharp edges on one end and another end fixed to the supporting frame. Three core cutters have been fabricated in total, made out of stainless steel. The physical characteristics of the fruit are considered in order to design the size of the cutters [2]. All the cutters fabricated are of 10 cm long with varying diameters (5, 4.5, and 4 cm) and can be removed so that it can be altered to handle fruit of different sizes.

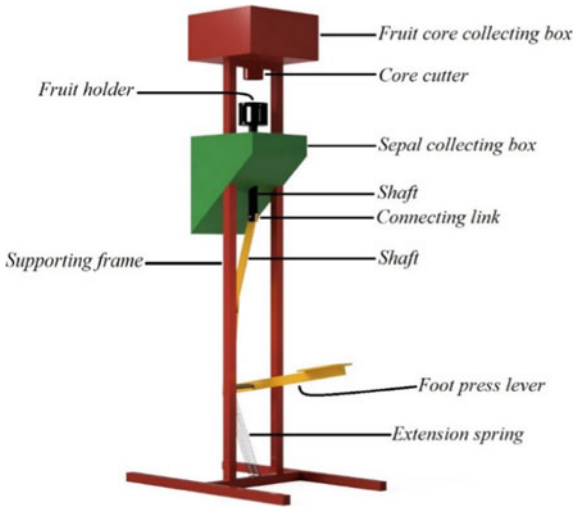

Fig. 3 Layout of foot operated MCC with detailed parts

Fruit holder

The purpose of the fruit holder is to hold firmly and push the fruit upwards core cutter throughout the process to remove the core. The fruit holder attached to the shaft operates on the reciprocating motion principle, with the fruit holder moving upward due to the mechanical friction induced by the applied pressure on the foot press lever.

Foot press lever

A foot press lever is linked to the fruit holder for pushing it upwards core cutter by means of shafts made of mild steel rod/pipe by means of four connecting links. The length of the foot press lever was fixed at 46.5 cm based on ease of use, convenience, and versatility. It was also found to be satisfactory from an ergonomic standpoint. Based on convenience, strength, and grip stability, the length of the foot rest has been set at 10 cm. The foot rest has a textured surface made up of geometric circular bumps for improved stress relief throughout the operation. The overall foot press lever is engineered to provide the required force for operating the foot operated MCC.

2.3 Operating Principle

The foot operated MCC consists of supporting frame, core cutter, fruit holder, collecting boxes, connecting links, extension spring, and foot press lever. A force distribution foot press lever is connected to the adjacent shaft with a link connected in between the two square pole of the frame. The shaft connected to foot press lever is connected to two other shafts (using links) with one shaft attached directly to the movable fruit holder with a link connected in between the two square pole of the frame. The immovable core cutter is positioned at the top center of the frame and can be removed if required. Two collecting boxes are mounted directly to the frame, one below the fruit holder for collecting sepals and one above the core cutter for collecting the core of the fruits separately. The connected shafts are subjected to tensile forces as a result of pressing the foot lever [12]. The development of tension in the shafts in turn pushes the fruit holder upwards to bore the fruit into the core cutter. When the foot is disengaged from the foot press after use, the fruit holder and shafts revert to their original position due to the tension created by the extension spring connected to one end of the foot lever and base of the frame. When the fruit holder moves down, the sepal is gathered in the collecting box placed below the fruit holder. During this process, there is a chance that the fruit core may cling to the cutter die during this process, which will be easily removed due to the pressure developed while cutting of the other fruits. The fruit core will be collected separately in the collecting box placed above the core cutter. After the process completes, the sepal portion is easily chopped and processed into a variety of value-added products.

2.4 Performance Metrics

Ten experimental trials were used to evaluate performance metrics such as cutter capacity and sepal yield. In the sections below, we'll go over the standard method for evaluating each performance measure.

Cutter capacity

The machine's capacity was determined by calculating the mass of the fruits (kg) processed and the time (h) it took to process them [13] and is given by:

$$Q = \frac{W}{T} \times 60$$

where,

Q = Capacity of foot operated MCC, kg h^{-1},

W = Overall mass of fruits processed, kg,

T = Time required to process the fruits, min.

Sepal yield

Sepal yield is given as a percentage and is defined as the ratio of sepal's mass to total fruit mass [1] and is given by:

$$Y = \frac{W_2}{W_1} \times 100$$

where,

Y = Sepal yield, %,

W_1 = Overall mass of fruits processed, kg,

W_2 = Overall mass of sepals obtained, kg.

2.5 Statistical Analysis

Experiments were carried out in triplicate, and statistical analyses of the various trials were performed using SPSS software and Microsoft Excel 2019 [14]. For both approaches, ANOVA was used to evaluate the MCC efficiency.

3 Results and Discussion

The measurements of the foot operated MCC and its parts (Table 1) were determined based on the human physique and physical properties of the fruit. The conceptual design illustration and dimensions along with the different views of foot operated MCC are shown in Fig. 4. The fabricated cutter was put through its paces in experimental trials as shown in Fig. 5, and its efficiency was assessed, as discussed below.

3.1 Ergonomic Improvements in the Proposed Design

Cutting of an elephant apple fruit by sitting or squatting on the floor using traditional tool may lead to numerous MSDs. This MCC is designed based on human physique and average height of a person (5.6 ft). The fruit holder (working surface) is placed at a height of 3.3 ft that is easily accessible to a person of normal height. The foot press lever is designed keeping in view the ergonomic principles and thus following factors are considered which directly affect the overall performance:

1. The positioning of the fulcrum with reference to the foot.
2. The magnitude of resistance applied to pedal movement.
3. Foot dimension.

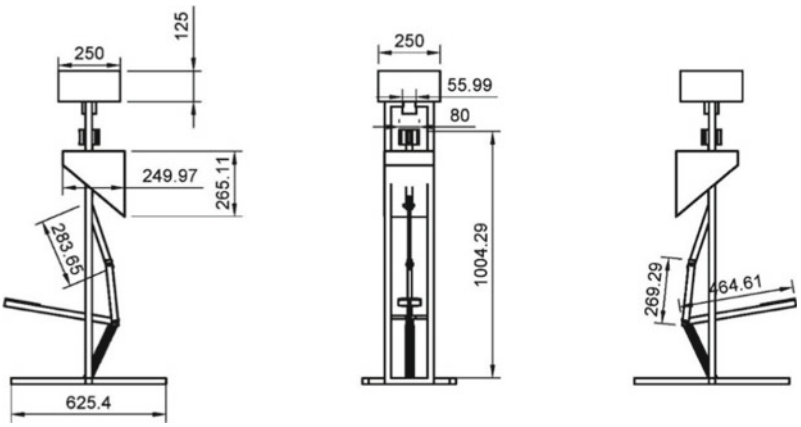

Fig. 4 Detailed specification and different views of the foot operated MCC

Fig. 5 Foot operated mechanized core cutter (MCC) during trials

3.2 Force Required to Press the Foot Pedal

To determine the force involved in pressing the foot pedal few factors are considered such as:

For the designed MCC

1. Mass (m) of load against pedal = 5 kg
2. Distance of load from the fulcrum = 11.5 cm
3. Distance from fulcrum to the foot pedal = 35 cm.

Here,

$$Mechanical\ advantage\ of\ the\ lever = \frac{Distance\ from\ fulcrum\ to\ foot\ pedal}{Distance\ of\ load\ from\ the\ fulcrum} = \frac{35\,\text{cm}}{11.5\,\text{cm}} = 3.04$$

$$Force\ required\ to\ press\ the\ pedal = \frac{mg}{Mechanical\ advantage} = \frac{5\,\text{kg} \times 9.8\frac{m}{s^2}}{3.04} = 16.12\,\text{N}$$

The force required to carry out the task is 16.12 N, which can be accomplished by any person easily and conveniently. Thus, this machine is considered efficient from every aspect of ergonomics and ease of operation.

3.3 Performance Evaluation

Experiments were conducted to determine how well the MCC performed. Compared to conventional method for 5 batches of fruits with 10 elephant apples with average mass of 460 gm each. The results of the experimental trials such as cutting time, mass of fruit processed, mass of sepals, pulp and percentage of sepal yield obtained are shown in Table 3. Performance metrics of mechanized cutter compared to conventional method, assessed through experimental trials are shown in Table 4.

It is noted from Table 3 that mechanized cutter cutting speed was approximately 7.47 times faster than the conventional cutting method. The conventional method took 1089.40 ± 46.71 s to cut 5 batches of 10 elephant apples each, while the mechanized cutter took just 145.80 ± 1.30 s. For the mechanized cutter, a lower standard deviation in cutting time meant less difference in cutting speed. From Table 4 it is observed that the mechanized cutter can process large amount (115–130 kg/h) of elephant apples than that of the conventional method (13–17 kg/h). The findings show that the conventional approach is not only time intensive, but also inconsistent [15].

The overall recovery (sepal and central core) for the conventional method and mechanized cutter was found to be 97.86 and 99.47%, respectively, reflecting that the conventional method leads to higher invisible loss (2.14%) than the mechanized cutter (0.53%). The gummy liquids spilled by damage to the florets of the elephant apple core, resulted in this invisible loss. The overall recovery was split into two groups in the study, the usable portion sepals, and the central centre, which includes smaller fractions of sepals. The conventional method yielded 14.64 kg (64.23 ± 2.43%) of sepal from 50 fruits (5 batches), while the mechanized cutter yielded 19.80 kg (85.55 ± 1.81%) as shown in Table 3. For the conventional method, a higher standard deviation in sepal yield meant more variation among batches. This meant that the conventional method resulted in a greater loss of usable fruit sections along with the central core compared to mechanized cutter. This may be attributed to the fruits being cored uniformly and accurately by a specially crafted cutter, resulting in less damage [15]. Since this factor is important for the commercial application of product obtained after processing, the MCC may contribute significantly in processing the final product with intact sepals. The findings correspond to the coring of the egusi fruit pulp [16].

The variance between cutting time for conventional methods and the MCC was evident (F_{cal}2038.42, F_{crit}5.32) from the single factor ANOVA with 1% error level. In addition, ANOVA for the sepal yield percentage obtained by MCC is considerably ($p < 0.01$) higher than the conventional method (F_{cal}247.49, F_{crit}5.32).

Table 3 Performance evaluation of mechanized cutter compared to conventional method (batch of 10 elephant apples each)

Batch	Conventional method					Mechanized cutter				
	Cutting time (s)	Mass of fruit (gm)	Mass of sepals (gm)	Sepal yield (%)	Mass of pulp (gm)	Cutting time (s)	Mass of fruit (gm)	Mass of sepals (gm)	Sepal yield (%)	Mass of pulp (gm)
1	1117	4643	2917	62.82	1628	147	4371	3680	84.18	667
2	1125	4528	3014	66.56	1429	145	4748	4118	86.73	611
3	1086	4389	2948	67.17	1336	144	4692	3911	83.35	749
4	1010	4467	2789	62.44	1585	146	4763	4079	85.64	658
5	1109	4783	2973	62.16	1703	147	4574	4016	87.80	536
Total	5447	22,810	14,641	321.17	7681	729	23,148	19,804	427.73	3221
Mean	1089.4	4562	2928.2	64.23	1536.2	145.8	4629.6	3960.8	85.55	644.2
SD	46.71	154.52	85.53	2.43	150.17	1.30	162.54	175.40	1.81	78.27

Table 4 Comparison of performance metrics of conventional method with mechanized cutter

Performance metrics	Conventional method	Mechanized cutter
Cutter capacity (kg h^{-1})	13–17	115–130
Sepal yield (%)	64.23 ± 2.43	85.55 ± 1.81

3.4 Cost Analysis

The materials used for fabricating the MCC is presented in Table 1. The estimated cost of the mechanized cutter covers the labor costs, and it was estimated using the market value of the raw materials used in the core cutter's fabrication [17]. Fabrication of the cutter costs nearly Rs. 3000. The life of the cutter was assumed to be three years in this design, with an average use of 1000 h annually. For the MCC, the cost of operating per hour is estimated to be Re. 1. This demonstrates that the mechanized cutter would undoubtedly meet the demands of farmers and local manufacturers for large-scale elephant apple processing at an economical price.

4 Conclusion

Equipment that is ergonomically well constructed reduces workplace health risks and improves job effectiveness. As a result, designing equipment with an emphasis on comfort is no longer a luxury, but a requirement. In order for a machine to be well-designed, it must be directed towards achieving the purpose rather than the design. Also, while designing the equipment, other factors to be considered are: components that should be available locally, farmer's necessities, and ease of operation. The performance metrics of the mechanized cutter were better than that of conventional method, according to the overall review of the experimental findings. Ergonomically, the MCC designed is found to be suitable in all aspects from operation to handling. In terms of performance, the mechanized cutter offers higher sepal yield of 85.55 ± 1.81% with cutting capacity of 115–130 kg/h, and more uniform coring of the finished product than the conventional method, with sepal yield of 64.23 ± 2.43% and cutting capacity of 13–17 kg/h. The machine is economical and has a basic mechanism. It is simple to use and can be made from materials found locally. This is particularly suitable for use in NE Region of India, where no mechanized cutter is available until now. It may be used in elephant apple processing by farmers or local entrepreneurs in order to allow them to gain value for further commercial and therapeutic applications. The industrial use of this underused fruit by standardising the operating methods and adding value can enhance the well-being of the residents of the area and can also make significant contributions to the national economy.

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Photography Is a Tool of Social Awareness

Bappa Das and Debkumar Chakrabarti

Abstract Photographs are an essential medium for raising human awareness. Proper use of photography is crucial for raising social awareness. The field of visual communication has emerged political communication, advertising, information, and other media effects. As a result, one of the primary reform initiatives of the Government revolves around spreading awareness through photography on various social issues. In this situation, it may be stated that visual communication mediums like posters, banners, and hoardings play a significant role in enabling such initiatives to develop social awareness at a larger scale across the society. A photograph is a long-lasting and a significant tool for spreading the message to the target group; the awareness campaigns by the Government sizably depend on such a medium to reach out to a large number of audience. Photography has often promoted the social interests of people. Communication is the action of sharing ideas and information as well as the exchange of knowledge, attitude, and feeling between two people or a group of people. The study confirms that combining images and text with a sentiment attached to it for a social campaign, may get better acceptance.

Keywords Communication · Photograph · Poster · Awareness

1 Introduction

Communication plays a vital role in conveying a message through photographs. The twenty-first century is called the digital era for any context. Visual display for communication is one of the most significant ways [1]. Communication is a crucial factor in photography. The power of a visual image is essential for emotion building and influencing our conscious thoughts [2, 3]. Photography bridges two things, first the viewer or target audience, and the second being the image producer. Photographs help to create awareness among the people. It helps to create an emotional impact on

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the target people [3, 4]. An image can generate a lot more connection than written words, and we become more dependent upon visual media sharing information, education, and socialization. Visual information affects people's senses and images to convey a message [5]. It also pursues to guide the viewer to interpret the image the correct way. It then suggests the proper manner of seeing, explaining, and expressing an opinion in an image [6]. Images signifies reality; images shows truth and facts to the society. Photography is one of the easiest accessible mediums to create awareness for a target group [7]. Visual communication creates a connection between two factors. The first one is trying to say something, giving information, a message for a particular fact, and many more. Image communicates efficiently because it has an excessive impact on people [8]. Photographic elements like composition, subjects, lights, texture, moments, and color will help us understand the context of a particular image or photograph. Photographic approach to make the target audience aware for natural or any other social issues experienced and enhances social emotion [9]. An image is an iconic tool. Expressing awareness and creating awareness is real visual understanding. Any photograph can capture each moment of humankind [10]. In a country like India, where various communities, their languages, culture and lifestyle is different than others, communication with Indian people is not a very easy task. It is important to understand all the limitations of people's acceptance and thoughts [11, 12]. Images assist to deliver message, but the way of communication with the target people should be the main focus. The right target audience should connect themselves emotionally with the awareness photograph [13].

2 Objective of Study

This study aims to comprehend a photograph to create social awareness. It is anticipated that the image or photograph influences the target audience to understand the social message it aims to spread. There are several types of social awareness campaigns where each one is different from the other. Every message should communicate with the target audience; if it's not clear to them, that means the photograph or image used for a particular awareness message is not appropriately represented. The way the photograph / image should be used that promotes social awareness message.

3 Methodology

A systematic review has been conducted from few select research papers, journals, and Indian government portal. This study reveals the contemporary awareness poster design for a specific group of people. India experiences extensive culture and language diversity; and the content of awareness campaign also vary to address target specific people. The Government of India plays a key role in promoting social awareness. Commonly these were in the education sector, nutrition, social equality,

swach bharat, family welfare, food and health. 12 posters have been shown to the participants. Three popular posters seen commonly displayed on Indian government web portals and panchayat offices, have been selected through the random selection process for this study. All the posters are selected by the participants.

Three states were visited for on spot observation, one is West Bengal, and second one is Maharashtra and third one is Karnataka to see if any commonality in views exists. Sasewadi is a medium size village located in Bhor Taluka of Pune district of Maharashtra was chosen where the literacy rate of 84.15% (https://www.census2011.co.in) compared to 82.34% of state average. Hanshpukur is a large village, located in Mahestola block of South twenty four Parganas district, West Bengal and the rate of literacy is 56.18% (https://www.census2011.co.in), which is lower compared to the state average. Bangalore district is located in Karnataka, and average literacy rate 78.21% as per census data 2011 (https://www.census2011.co.in).

Three groups of people have helped in this study. Table 1, (A) students, (B) the target population of Villagers/Common people and (C) Urban people. Students group was formed with design learners and different subject students (MBA, Engineering, commerce). Students of design program were selected who have relevant design elements inputs and can apply the same in design application. For the other students studying varied subjects were selected randomly for generic opinions.

The villagers/common targeted users group is formed of common people for whom this awareness programs is being developed. This targeted group has two other sub-groups. One is the common village people and another side of the same group is city people, who live in city. A third group was also considered as an urban people group. Above group of people can think about this present scenario of the awareness campaign, the volunteers were considered on purposive selection basis.

The study comprises three surveys where three different posters were displayed to participants for their understanding.

Table 1 Survey participant's details

Number of participants and background			
	Headcount	Background of participants	Method
Students	37	Future designer and other discipline	Poster image without relevant text
Villagers/common people	54	Farmers, housewife, worker, service	
Urban people	17	Service/professionals	
	Total: 108		

4 Observations

Below are the responses.

Survey—1

In the Indian Government social campaign photographic poster, shows a woman (Fig. 1) sitting on a bicycle with two young children. There is a sun rising effect background with two solid colour patches. All have a smiling face and are front facing. These all are the contents of this social campaign photographic poster. The main content are the three photograph of human figures. According to design importance, the women figure covered more space than other elements.

The survey outcome is presented in Table 2. As usual, most of the participants consider this poster as women related. 24 participants said this is for "Happy Family." 21 people said it might be "Female and Male Equality" related campaign. Some of the participants think this is for Cycle Promotion. 18 participants think this is for Physical education. Few numbers of participants are confused because of the image priority. 16 numbers of participants said this was for "Women Empowerment" or "Women Can Do Everything." It is clear that this poster photograph is communicating as per the social campaign issue. Interaction or communication through image or photograph is

Fig. 1 The poster without the text content was used for survey study-1 (Image *source* National Rural Health Mission)

Table 2 Survey outcomes on Fig. 1

Comments on	Number participants
Happy family	24
Cycle promotion	8
Physical education	18
Women can do everything	16
Girls and boys are equal	21
Female equality	13
Don't know	8

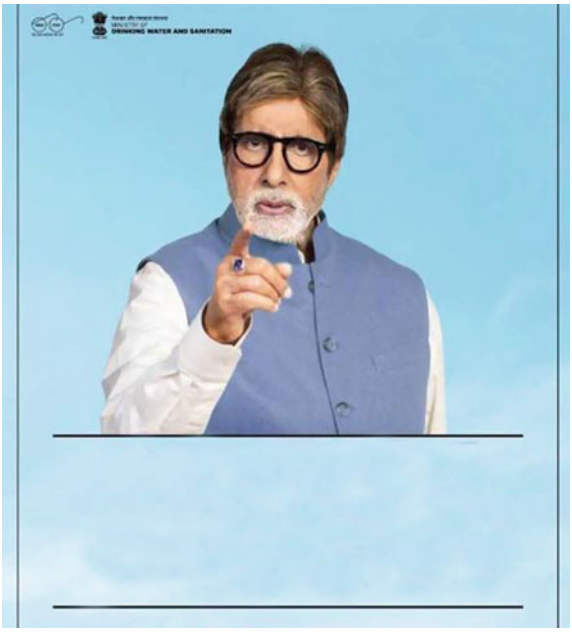

Fig. 2 The poster without the text content was used for survey study-2 (*Image source* Ministry of drinking water and sanitation)

reaching to the target audience in various ways. Individually entire image/photograph convey several message.

Survey—2

The poster (Fig. 2) was created with a famous Indian actor Amitabh Bachchan, a well-known personality in the Indian cinema. As one can observe there is only human figure image is in this above poster, with no textual content is there. His facial expression and the finger pointing to saying something or maybe instruct something to the viewer. In the beginning, all the participants were saying it is a "Toilet Wala Poster" (Poster of the toilet campaign). But after a few moments, they all changed their opinion. Government publishes this poster for social communication to create awareness among the target people. The main motto of this poster is to aware people.

Table 3 Survey outcome on Fig. 2

Comments on	Number participants
Polio	48
Swachh Bharat	19
TB	20
Toilet	12
Don't know	9

Table 4 Survey outcomes on Fig. 3

Comments on	Number participants
Safe driving	22
Child safety	9
Swachh Bharat	23
Education related	16
Tourism	19
Mothers safety	16
Don't know	3

In this poster, human image is too dominant than any other content and color or texture. Table 3 survey response says, out of the 108 participants, 48 people are saying this is a "Polio" campaign poster. The main question that lies ahead of us, is that how can use a photograph for social awareness campaign if the content is not understood clearly by the target group.

Survey—3

Celebrity image for awareness campaign design might influence target people. Indian government is not exceptional on this cause. In this poster one of the most popular photographic human figures used for government awareness campaign. This type of image is very easy to connect with target group of People. This celebrity image itself is very commonly used for communication. It is easy to grab the attention of the passers by, consciously or unconsciously considering general people.

From this survey, people easily recognize the same image as per the photograph. Many participants believe this poster belongs to child safety, some of them think this photographic poster belongs to swachh Baharat campaign. Many participants said this campaign photograph is related to tourism and education. Even, few participants have express that this is for safe driving.

One photograph can carry different messages for different people (Table 4).

Fig. 3 The poster without the text content was used for survey study-3 (Image *source* Ministry of Women and Child Development)

5 Conclusion

According to the present survey—photography on social awareness, each individual photograph influences viewers. Celebrity image, target audience photograph also used for social awareness campaign design. All the photographs have been used according to the context and target audience and their understanding. According to the contemporary social awareness photograph, target people usually interact by the specific image. Essential to use of photographic image for these types of social awareness campaigns. All the participants spontaneously interact with celebrity photograph or target audience photograph, the significance of the photographic image to express the message is undeniable. Their emotional attachment, thoughts on photographs, various way of interpretation, prove that "A picture is worth a thousand words" (Henrik Ibsen). But it is safe to conclude by the study that, to convey a specific message a text content requires to be accompanied along with the image, else there would be a high chance for misunderstanding.

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Multipurpose, Low-Cost and Electricity-Free Cold Storage Cum Vending Cart for Vegetable and Fruit Vendors

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Abstract The unorganized sector highly contributes to economic growth in India and provides enormous employment opportunities. Street Vendors form an inevitable and prominent part of the unorganized retail sector. Fulfilling the daily needs of almost every Indian household, they are considered the lifeline of every Indian city. In recent years, the organized sector has enormously increased, posing a great challenge to the unorganized sector. Unorganized retail dwelling upon traditional technology setup and constrained funds is not able to compete with superior technology and infrastructure-based organized retail. It severely affects the social structure and occupational well-being of the unorganized retailers, especially the street vendors. There lies a dire need to equip them with technology-enriched low-cost design interventions that may empower them to compete with the organized retail. Several researchers have advocated the need of designing and developing context-specific design interventions as a mitigating solution. In the present research, the authors have looked into the problems and challenges faced by street vendors and proposed a low-cost, multipurpose vending cart to empower the street vendors. It will enable them to compete with their counterparts. Its market potential, probable user-acceptance, and enablement aspects have been tested and accumulated using the System Usability Scale and securing Intellectual Property Rights. This paper highlights the developed innovative intervention with its working details. It may act as a ready reckoner and potential literature source for the researchers, entrepreneurs, social scientists to develop similar kinds of innovative solutions to equip the lower strata population for their betterment and occupational well-being.

Keywords Product innovation · Low-cost design solution · Bottom of pyramid · Design intervention · Human-centered design · Occupational well-being

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1 Introduction

The modern Indian retail market setup comprises three entities viz. unorganized retail sector, organized retail sector, and the E-tail. The significant share belongs to the unorganized sector. Retailing in India accounts for over 10% of GDP and 8% of total employment. The unorganized retail sector dominates the Indian retail market; it forms around 90% of the total Indian retail market [1]. With the advent of liberal government policies and Foreign Direct Investment (FDI) funds, the organized sector is proliferating and is squeezing the unorganized sector. In recent years, the technology-backed E-retails have taken up a great leap and had become much popular. The organized retail and E-tails enjoy a sound technical superiority, large pool of funds, better infrastructure and facilities, efficient asset management, etc. In contrast, the unorganized sector posses meager financial resources, traditional infrastructure, limited access to public facilities and resources, etc. Despite these limitations, it is the lifeline for the vast majority of the Indian population. It caters to the needs of millions of Indians to earn their livelihood and sustain themselves.

In unorganized retail, street vendors play a significant role in the Indian market and economy and impact the livelihood of almost every Indian household. They help deliver the daily necessities (vegetables, fruit, dairy products, bread, etc.) in their vicinity. As such, they become an integral part of the society to keep its pace smooth and prosperous. Unfortunately, they often remain neglected in government policies and resort to relying upon traditional infrastructure, inefficient technological setup, marginal public facilities, etc. This hampers their growth and social welfare and leads to poor occupational well-being [2]. Moreover, in the present scenario, they face strong competition from organized retail and E-tails in the technological era. They are unable to compete with them, and it adversely affects their livelihoods. The stiff challenge posed by organized retail and E-tails had impacted the lives of marginal street vendors a lot [3]. In modern Indian society, with the contemporary concept of smart cities, several infrastructure changes had happened gradually. With the emergence of supermarkets, E-tails, and home delivery networks, the corporates are directly reaching the customers. It eliminates and diminishes the scope for the street vendors to earn their living. The rate of such expansion is relatively high, and there is no effective strategy to protect the interests of the street vendors. They face a tough challenge to survive and earn their livelihood in the modern context [4].

There lies a dire need to look after the plight and to equip them with several amenities, infrastructure, etc., that could enable them to compete with the technologically sound organized sector and dwell their lives with prosperity. However, there lies a paucity of such efforts from government agencies, social entrepreneurs, and researchers. The actions to empower the street vendors had witnessed a shallow path. Government policymakers have struggled to recognize street vendors as legal or important entities. Although they have formulated various strategies and regulations to protect their rights, they face a tough challenge in their implementation due to a large population engaged in this profession [5, 6]. A few researchers have made an attempt to understand the complexities associated with the unorganized

sector and its impact. Newspapers had, however, remained vocal to raise the issues of street vendors, but such attempts remain on a local level and had a lesser impact. Often such news against the atrocities being faced by them appears in the columns of newspapers and magazines within the tier II and III cities [7–10]. Few researchers have advocated to design and develop context-specific design interventions and the implementation of those at local levels to improve health, safety, mental health, and occupational well-being [11].

Realizing the need and importance of street vendors in the Indian economy, the researchers in the present research focused on understanding the issues and difficulties faced by the marginal street vendors. The attempt was made to develop a design intervention to empower and equip them with a feature-rich technology-oriented vending cart. It is capable of providing ease, comfort, and humanizing the work of the street vendors and will help them compete with technology-based organized counterparts. This attempt and approach may further encourage other researchers, social entrepreneurs, and government agencies to conduct such studies and devise policies for the social welfare of the vast majority of street vendors.

2 Methodology

In the initial phase of the present study, the several street vendors plying within the streets and weekly markets located in tier II and tier III Indian cities were observed to have an understanding of their daily routine and functioning. The tier II and III cities were chosen as they have a large population of street vendors and are in line to be converted into probable smart city infrastructure as per the recent government policies. The preliminary observations helped in understanding the street vendors' inherent work parameters, business strategy requirements, commonly used tools/equipment/devices, available infrastructure (vending cart, rickshaw, rehri, etc.), available space allocations, ease to public spaces and facilities, educational level, etc. Further, Guwahati city was chosen for the practical reasons of conducting an in-depth and practical study. Guwahati is a major city in the northeast Indian region that engages a large population in unorganized retail activities. Recently it had been chosen for being developed into smart city infrastructure by the government of India. The Paltan Bazar and Beltola are its prime business locations and economic hubs. The street vendors engaged in business activities in these localities were selected as a target group. Several street vendors in these areas were interviewed to understand their routine work, pain and frustration points, likings and dislikings about present infrastructure owned, features and requirements in prospective infrastructure, financial capabilities/limitations to own customized infrastructure, etc. These approaches provided a lot of understanding of the need/requirement and features they anticipated in the intended product/equipment. It helped to understand their problems, probable causes, and anticipations from the research community, well-wishers, and government. Based on their immediate need, a design intervention in the form of a multipurpose vending cart having provision for technological features was designed

and developed. The intended innovative design intervention is capable of catering to the specific needs of vendors. It will equip them with modern technology features to remain competitive within the prevailing dynamic market scenario. User surveys were conducted to get feedback from the target groups to know the pros and cons of the product developed for further future improvisations. The researchers obtained the Intellectual Property Rights (IPR) to retain the exclusive rights towards the further development, marketing, and licensing needs.

3 User Study and Design Intervention

Within the Guwahati city, the market area, haats, narrow streets, and large public areas of Paltan Bazar and Beltola locality were visited on a routine basis to interact and interview with the street vendors. It provided insights in regard to their problems faced and anticipated solutions. The user feedback gathered thereby is provided in subsequent sub-section.

3.1 Problems and Issues Faced by Street Vendors

The vendors reported several problems and issues that were of great concern and needed immediate attention from researchers and governmental agencies to frame/draft policies to address them in a better way. Such issues can be broadly categorized into four categories. These are discussed in subsequent sub-sections.

3.1.1 Vending Space Related

The number of vendors existing in these areas is rapidly increasing. However, the available vending space is limited and scarce. It leads to struggle for optimum space required to fulfill their needs. Hence the major issue faced by the majority of vendors is space scarcity. In order to procure the required space, the vendors resort to the encroachment of footpaths, bye-lanes, parking lots, even the major part of roadsides. It leads to chaos and law and order situations sometimes. Such encroachments create a hassle for commuters and customers. There hardly remains a walking space to move around for shopping needs. Moreover, the regular vendors have virtually secured and maintained their vending location and have formed a boundary with mutual understanding. The disputes happen regularly with the new vendors entering the market and lead to awkward situations. These issues can be summarized as:

- Shortage of available space required for vending
- Lack of space allotment mechanism
- Disputes among regular and occasional vendors

- Disputes among native and migrant vendors (community-specific)
- Space lessee supports the vendors paying higher taxes (favoritism)
- Lack of space for the storage of saleable material
- Inadequate facilities for shelter/night stay/environmental challenges (rain)

3.1.2 Financial Issues

The profit margins of these vendors are very limited, and any additional financial implications mean a huge burden for them. Apart from the charges levied by the municipality corporation, an additional burden is often inflicted on these vendors. These areas have been given on lease, and the lessee tends to collect excessive taxes. Additionally, unlawful and forceful contributions (chanda) collected by the local youth clubs, goons, etc., is a social menace and impacts these vendors financially.

- Fees and applicable charges (legal government charges)
- Excessive tax collected by the lessee
- Lack of monitoring on lessee by Guwahati Municipal Corporation (GMC)
- Illegal/forceful chanda collected by local youth clubs for festivals, etc.

3.1.3 Safety and Security Issues

Apart from collecting extra taxes and illegal chanda, the youth clubs, lessee, and goons often assault the vendors when they fail to comply with their demands. It leads to social security and always remains a grave concern.

- Assault by youth clubs for chanda
- Assault by lessee for excessive taxes
- Assault by local goons on vendors staying overnight (during the night)

3.1.4 Inadequate Basic Facilities and Amenities

The street vendors have limited or negligible access to basic civic amenities, such as toilets, drinking water, covered shelters, lighting facilities, first aid centers, etc. Such public facilities remain in paucity in overall market areas and are of grave concern.

- Lack of toilets/drinking water
- No shelter against heat/rain/storm, etc.
- Inadequate lightening facilities (for dark hours)
- No first aid facility available

From the issues reported above, it is pertinent that the lives of street vendors remain miserable. They bear hardships due to neglect from government support, mismanaged implementation of provisions/policies framed for the protection of rights of street vendors, atrocities by social elements, inadequate technology and infrastructure, etc.

There lies a need to have strict government monitoring in their management. Simultaneously, the researchers can make an effort to provide them with cost-effective solutions to promote their occupational well-being. Overall, a conducive environment may be created for such vendors by the joint effort of both.

3.2 Innovative Design Intervention as Mitigating Solution

The issues/challenges faced by the street vendors need immediate attention both from the government and individual researchers. The policy formulation and strict implementation of those can be catered to well by government agencies. The individual researchers may design and device context-specific innovative design solutions to empower them. In the present research, taking into account the issues faced by the street vendors, e.g., lack of basic amenities, improper shelter related, inadequate storage facilities, etc., were tried to resolve by designing and developing a multipurpose low-cost vending cart as a context-specific design intervention. The development phases involved, features, and working details are discussed in subsequent sub-sections.

3.2.1 Prior Art Search and Ideation for Solutions

Initially, the issues identified were converted into mind maps and were converged to get/propose outputs/effective solutions for various issues. The rigorous brainstorming sessions were held among the researchers. Several concepts of the intended design solution were conceived, thorough consideration for the majority of the features required as per the need of the vendors were tried to incorporate. From the series of brainstorming sessions, few ideas were found prominent, and their further scrutiny for novelty, effectiveness, and ease of operation was decided to be assessed in detail. The three-dimensional product models and renderings were prepared to have a thorough look at the product's feel and appearance. Product architecture to encase all the required features into an aesthetic apparatus/ device look was visualized. Further, the newly ideated technology (incorporated into the innovative design solution) was rigorously compared/tested with the existing technology using prior art search within the existing utility and design patents worldwide. The results/inferences drawn from the prior art search reports provided insights into its novelty, non-obviousness, and effective industrial use that motivated the researchers to harness its IPR value by further filing utility and design patents.

In addition, its future readiness was further explored, and thoughts were given on making it compatible with the proposed smart city infrastructure. As a measure for its future improvisations, it was proposed to be smart in terms of multitasking, intelligent to predict future requirements, and finally be able to make its own decisions to enable its Artificial Intelligence (AI). Although, at the grass-root level, the requirement of AI may not be the need of the hour. However, the solutions offered should be data-driven

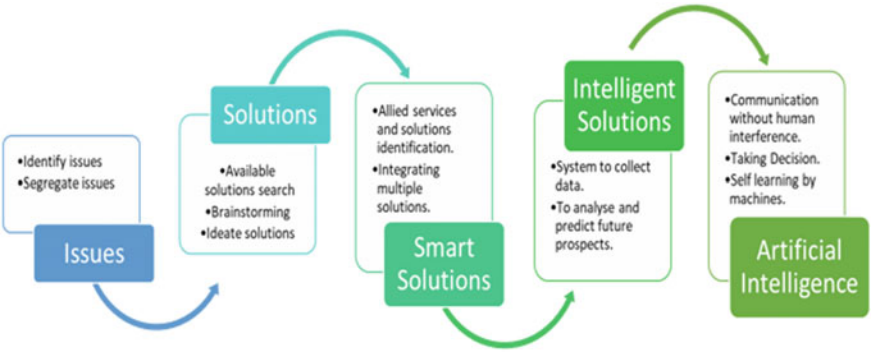

Fig. 1 Form issues toward smart and intelligent solutions: an approach. *Source* Author

and could be easily convertible to AI. Figure 1 depicts such an approach emerging from issues and resulting in AI solutions.

3.2.2 Innovative Design Intervention: Components, Features, and Working

The intended innovative design intervention is a tri-cycle-based low-cost vending cart having multipurpose features to cater to the needs and issues of street vendors. Primarily, it provides a low-cost cold storage unit working on the principle of evaporative cooling. In addition, it has provisions for the storage of potable water, a shed for protection from sun and rain, a lighting facility for late hour vending, shelter for an overnight stay, a power source, and devices like a fan for comfort during hot days, etc. Overall, it is a portable type vending cart that can be converted into a self-sustained, full-fledged fruit, vegetable shop at any location with sufficient space.

Components

The basic components of this design intervention are: a tri-cycle vending cart, cold storage cabins, two detachable water tanks, front and rear cabin walls with holes, layers of Khus (dried grass), solar panel, LED light, fan, exhaust fans, batteries, perforated PVC channels, half-slit PVC channel, geogrid or PVC mesh containers, portable shed with tarpaulin rolls, valves to control the flow of water. These are arranged in a sequential manner and arrangement to perform the intended functions as per need and requirement.

Arrangement

The arrangement of those components lies within three cabins. The main/primary cabin is mounted on the chassis of a tri-cycle. Another two small cabins form the second layer of the primary cabin. All these three cabins consist of PVC mesh baskets filled with vegetables. The front wall towards the driver in all the three cabins are having multiple openings to let the air enter through it. Just behind the front wall, a

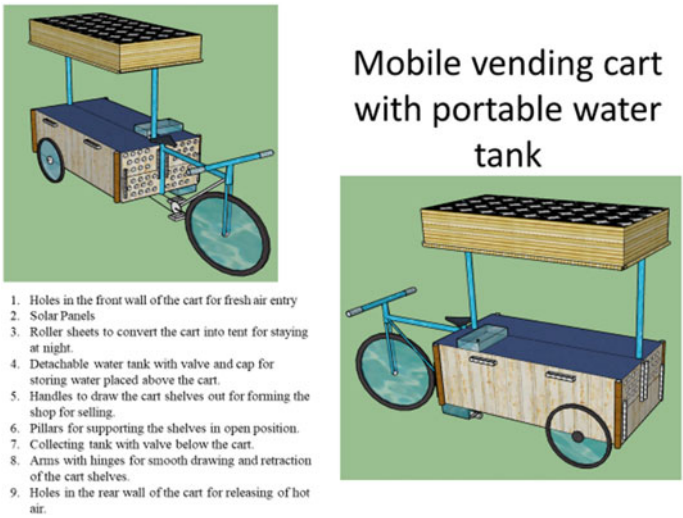

Fig. 2 Portable vending cart: components and arrangement. *Source* Author

layer of Khus is positioned. The Khus is aligned with a perforated PVC channel in the top cabin and a semi-slit PVC channel at the bottom of the main cabin (Fig. 2).

When the cart is ready to drive/move, all the water cycle components fall under the same alignment. At the top lies the intake tank with a valve to control the flow of dripping water that is connected to the perforated PVC pipe for uniform water distribution on the Khus of the top layer. This is followed by the dripping of water from the top cabins to the bottom cabins through the PVC mesh floor in that particular section. The water-dropping through the PVC floor of the top cabin falls on the Khus of the bottom cabin, and finally, it is collected in the semi-slit PVC pipe placed at the bottom cabin to recover the remaining water. The remaining water is collected in the collection tank through a semi-slit PVC pipe. The water collected in the bottom tank can be refilled in the intake tank through a manual pump attached to the tri-cycle.

The vegetable baskets are arranged in a zig-zag manner to manage/attain the airflow to pass through all the corners of the cabin. At the rear end, only the top cabins are provided with holes for letting out/escape the hot air. The floor of the top cabin is made up of PVC mesh at both front and rear ends. At the front, it is provided for dropping water, and at the rear, it helps to pass hot air from the bottom cabin to the top cabin, utilizing the holes in the rear wall (Fig. 3a, b). The top of the cart is covered with a solar panel, and the batteries are stored just below the solar panels in a concealed box. The batteries are connected with LED lights, a pump, a fan, and two exhaust fans attached at the rear opening.

Working

This innovative setup is capable of working as a cold storage unit to keep the daily necessity products (fruits, vegetables, dairy products, etc.) afresh in both conditions

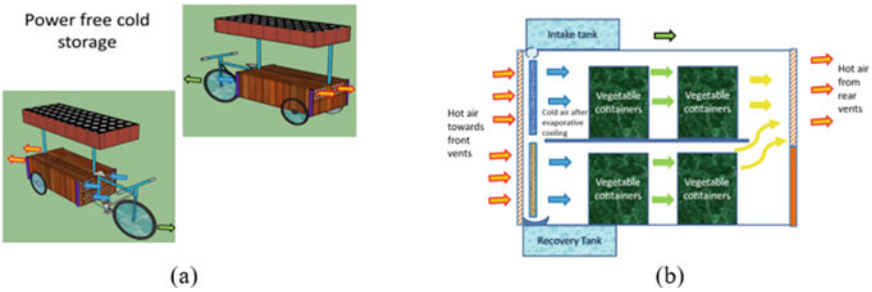

Fig. 3 **a** Air flow profile (front and rear), **b** air flow profile (within chambers)

viz. without any power backup (while moving), with power backup (in a static position). The vendor can load the cart with his products within PVC mesh baskets and lock them in a secure manner to drive safely on street roads. Once the vendor is ready to pedal the cart, the valve of the intake tank is opened. Depending on the outside temperature, the flow of water is regulated to achieve efficiency. When the cart is moving with pace, the air enters from the front wall openings, and the water continuously drips through the Khus of both the cabins. The air passing through the wet Khus evaporates the water, taking away the heat from the air. It enables the crossing air to cool. It further passes through the vegetable corridors arranged in alternate positions within the vegetable basket cabin. This cold and moist air preserves the vegetables from drying and decaying.

Simultaneously, the air from the bottom cabin reaches the rear wall and moves through the bottom cabin ceiling made of PVC mesh. The cold air remains in the bottom cabin releasing the hot air from the rear wall of the top cabin. At the same time, the air passing through the top cabin passes directly out through the rear wall openings. This arrangement helps keep one cabin moist and the other cabin only cool (with lesser moisture). The green leafy vegetables that require moisture can be stored in the bottom cabin, and the dry vegetables like potato, onion, ginger, garlic, etc., demanding less moist conditions, can be kept in the top cabin. Upon continuous use, the top tank may go empty. When it happens, the bottom tank is lifted, and the top tank is refilled again with the recovered water. This cycle goes on a repeated basis to keep the cold storage unit active and efficient (Fig. 4).

This innovative vending cart can also be used as a temporary shop/stall in a halted position at designated vending spaces. Such a stationary vending shop may help the vendor in his operations and promote occupational well-being. Upon reaching the designated selling places, the vendor can draw out the cabins with the help of handles, hinged arms on either side of the cart to convert them into a stationery vegetable shop (Fig. 5a, b). The driving seat and handle can retract/ collapse to utilize lesser space. The shed to cover the cart (temporary shop) can also be erected. The shed is extendable to the limits of the shop. Tarpaulin rolls attached at all the edges of this cart enable the vendor to convert it into a tent to stay overnight (Fig. 5c) and spend the night comfortably (if required). All four rolls can be attached to each other

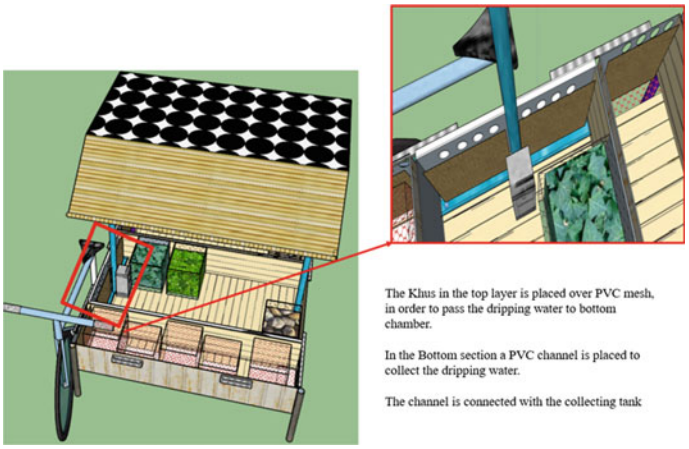

Fig. 4 Evaporative cooling setup acting as a cold-storage unit. *Source* Author

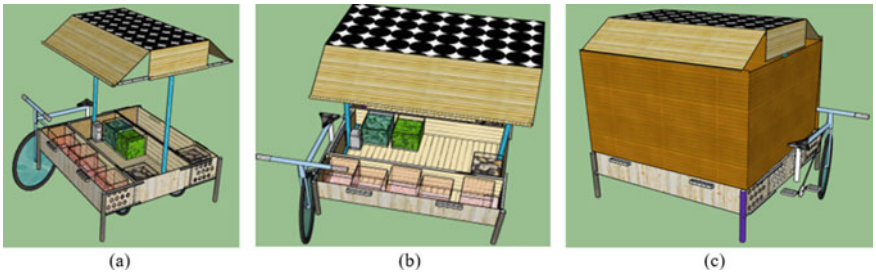

Fig. 5 **a** Convertible shop with shed, **b** convertible shop with shed, **c** temporary accommodation set-up

with the help of a zip. This entire frame is made up of hollow tubes, and sheeting is done with the help of glass fiber to make it lightweight, waterproof, a good insulator, yet strong enough to carry sufficient loads. Four pillars are provided at the end of the top cabin. These provide strong support to the storage cabins once the cabins are drawn out to form a shop.

At static locations, power generated through the solar panel is used to operate the fan, pump, LED light, charging point, etc. Power storage batteries are provided for this purpose, and these can also be charged at residence as per requirement. The exhaust fan attached to the rear wall of the top cabin is used to induce draught by utilizing battery power while the cart is static/parked. The induced draught creates/causes negative pressure and forces the outside air to enter from the front wall openings. The valve of the intake tank opens, and the water starts dripping through Khus. As such, heat exchange happens. The remaining water is collected in the recovery tank at the bottom. Once the water level reaches sufficient height in the recovery tank, the pump automatically pumps the water into the intake tank. This forms the operation

of the cold-storage unit in static condition while the vending cart is parked. During the daytime, the vendors can use the battery-operated fan for their comfort. At night the LED can be used as per need.

4 Discussion

This context-specific innovative design intervention (multipurpose, feature-rich vending cart) was demonstrated, and its working was explained to the 60 vendors in Guwahati city through presentation cutouts. Their feedback was obtained using the System Usability Scale (SUS) [12]. The SUS is used to measure the perceived usability of the system. Several researchers have proactively used it to evaluate the system's usability in mobile app development [13], healthcare devices [14], etc. The SUS score of 68 and above is considered significant. For this design intervention, the SUS score of 86 was obtained post feedback from the street vendors. This indicates that the vendors felt satisfied with the inherent features provided within the vending cart and its intended use. They exhibited strong trust, interest, and liking towards it. It can be assessed that they felt the developed product to be quite a promising one and indicated a strong desire to own one of such kind. The vendors well received it, and it can further be developed at the mass production level to benefit them. It is pertinent to note that such design intervention can empower them on technology upfront in a cost-effective manner and will promote their well-being to better their prosperity and positively affect their livelihood.

5 Limitations and Future Scope

The present study of street vendors in Guwahati city revealed various policy level problems and issues in the context of inadequate norms, poor mechanisms, implementation, effective follow-up system, etc. These hamper the growth prospects of marginal street vendors. Those must be taken care of by the government agencies on priority. In this paper, these issues were fetched and highlighted in detail. However, having proper focus and proposing concrete remedies to those remain beyond the scope of the present study. Those remain of primary concern for the concerned government authorities. The researchers, on their behalf, could only work on providing a cost-effective solution as a design intervention capable of addressing those issues to the broader context. In this context, researchers have not left any stone unturned to achieve the intended goal. The majority of the facilities, basic amenities, business features, etc., have been incorporated in the developed innovative intervention.

Presently, this vending cart covers the basic features and is not AI module compatible. However, in the upcoming improvisations, it may be made compatible with

modern smart city infrastructure. The AI-enabled vending and billing facilities integrated into a smart city's navigation systems can be further incorporated into it. The initial development cost of these vending carts may cost high, but it can be significantly reduced upon production of such vending carts on a mass scale.

The researchers have been granted both Indian utility patents [15] and Indian design registrations [16] for this multipurpose vending cart. The IPR value can be harnessed well in the future by licensing its commercial rights to the interested start-ups/ commercial agencies. Realizing its enormous market potential, the researchers themselves can further take up its development by obtaining seed funding from concerned government agencies. Overall, such a user-centric innovative product must be developed by either party in the future to empower the marginal street vendors to promote their occupational well-being and prosperity.

6 Conclusion

By implementing a carefully designed research methodology, the present research successfully provided a user-centric innovative design intervention in the form of a cost-effective multipurpose vending cart. It is capable of providing multiple services to the street vendors viz. mode of transport, cold-storage unit, convertible shop, and temporary accommodation. It will enable and empower the marginal street vendors to compete with the technology-backed organized retail sector. It will enhance their occupational operational ease, efficiency, livelihood earnings, prosperity, and well-being. It is cost-effective, easy to use/operate, and has vast potential to become a highly sought-after marketable product. It is expected to enable the street vendors to remain competitive in the ever-changing dynamic Indian market structure and promote their prosperity and well-being.

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Re-design and Ergonomic Assessment of a Handcrafted *Kalash* Polishing Equipment

Krishna Chaitanya Mallampalli and Swati Pal

Abstract In India, the handicraft industry is one of the important and export-oriented industries. In this industry, around six million handicraft workers were engaged, and their activities were mostly manual in nature. Polishing activity is one of the most essential activities in handicraft manufacturing. Polishing handcrafted *Kalash* is a traditional activity performed by the polisher of the Hajo brass metal cluster, Assam, India. These polishers perform this traditional activity using conventional polishing equipment in squatting positions for long hours, which requires enormous physical effort. Due to this uncomfortable situation, polishers have exposure to risk factors of work-related musculoskeletal disorders (MSDs). The present study, therefore, interviewed forty polishers regarding MSDs using the Nordic musculoskeletal questionnaire (NMQ). It was revealed that the disorders in the lower back, upper back, and elbows were prevalent among polishers. Further, postural analysis was conducted in Kinovea software. Using existing polishing equipment resulted in postural discomfort. Thus following the focus group discussions with the polishers, the existing polishing equipment was re-designed virtually in CATIA V5 software. Assessment of working posture in both the existing and re-designed equipment was carried out using the rapid upper limb assessment (RULA) tool. The results of RULA analysis showed that the working posture in re-designed polishing equipment was improved noticeably. Therefore, based on these preliminary findings, it is concluded that the ergonomically re-designed polishing equipment in the handcrafted *Kalash* polishing activity could reduce MSDs among polishers and makes the workplace comfortable.

Keywords Handicraft workers · Handicraft polishing · Ergonomic design · Musculoskeletal disorders · Posture analysis

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1 Introduction

Evidence suggests that work-related musculoskeletal disorders are one of the significant health problems in almost all occupations around the world [1–5]. These disorders are the main reason for work disability, functional limitation, reduced quality of life, long term sickness absence, and also cause a serious economic impact on individuals and industry [1, 6]. As a concern, preventing MSDs has become a major priority for both the developed and developing countries [1, 6].

In India, the handicraft industry is of vital importance to the country's economy. Also, it is considered as the second-largest sector in generating employment opportunities after agriculture. Around six million people were engaged in this industry, and international exports are increasing day by day [7, 8]. According to the provisional data, handicrafts exports have reached USD 231.17 million and recorded 13.5% growth in exports [8]. However, many previous studies reported that the handicraft workers suffer from occupational problems such as musculoskeletal disorders due to physical and psychosocial risk factors [2]. Besides these factors, some studies have also reported that the design of work equipment also contributes to musculoskeletal problems among handicraft workers [9]. Thus, designing work equipment ergonomically could ease the efforts of workers and results in the lower incidence of MSDs.

Like many handicrafts, handcrafted *Kalash* is a traditional handicraft item from Hajo, Assam, India. The *Kalash* is a round vessel that is made up of brass metal. It is most commonly seen in every household in northeast India. This traditional handicraft item is produced by handicraft workers of cottage industries. The typical manufacturing process of *Kalash* involves cutting, hammering, joining, and polishing. Among these manual activities, the most important and laborious activity is polishing.

The entire polishing activity is performed manually, including *Kalash* fitting, spinning, and polishing steps. The existing polishing equipment mainly consists of four parts: the wooden spindle (*Koloh Kunda*), bamboo sticks (*Gorokhila*), cotton rope (*Rhassi*), and sharp cutting knives. Figure 1 shows the existing polishing equipment. The dimensions of the existing polishing equipment are as follows: wooden spindle length 100 cm, height of bamboo sticks 30 cm, cotton rope length 150 cm, and cutting knife length 25 cm. Two polishers are required to accomplish the polishing activity. The person who polishes the *Kalash* is called *Bagi Dora,* and other supporting person is called *Koloh Tona.*

Figure 2 shows the typical working postures of handcrafted *Kalash* polishers. While performing this manual polishing of handcrafted *Kalash* with the existing polishing equipment, the polishers adopt a squatting posture for long hours, which requires enormous physical effort. Due to this uncomfortable situation, polishers have exposure to recognized risk factors of work-related musculoskeletal disorders (MSDs).

In this context, the present study gives importance to the areas requiring urgent intervention to safeguard the musculoskeletal health of polishers. The ergonomic design of work equipment is one of the recommended primary prevention measures

Fig. 1 The existing polishing equipment

Fig. 2 Typical working posture of handcrafted *Kalash* polishers

for abating musculoskeletal problems. Therefore, the present study re-designed the existing polishing equipment according to the user requirements and evaluated the working posture ergonomically in re-designed polishing equipment.

2 Musculoskeletal Disorders

Nordic Musculoskeletal Questionnaire (NMQ) [10] was used to determine MSDs among handcrafted *Kalash* polishers. Through this questionnaire, a total of 40 randomly selected polishers (*Bagi Dhora, (*$n = 20$); and *Koloh Tona* ($n = 20$)) were interviewed regarding their musculoskeletal problems. The questionnaire inquires

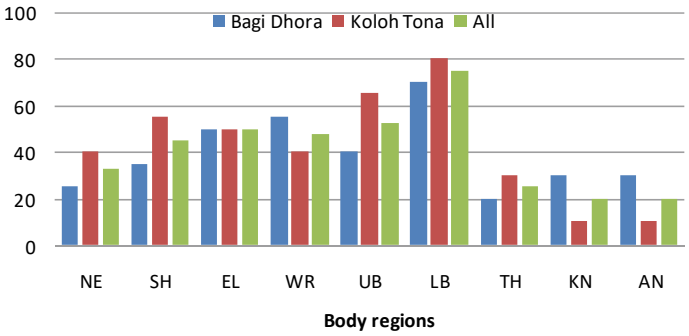


Fig. 3 Musculoskeletal disorders among handcrafted *Kalash* polishers. *Note* NE = Neck; SH = Shoulders; EL = Elbows; WR = Wrist; UB = Upper back; LB = Lower back; TH = Thighs; KN = Knees; AN = Ankles

about the history of musculoskeletal pain in the nine anatomical body regions (neck, shoulders, elbows, wrists/hands, upper back, lower back, hips/thighs/buttocks, knees, and ankles/feet) during the past 12-months. After analysis, it was revealed that the disorders in the lower back (75%), upper back (52.5%), and elbows (50%) were prevalent among polishers. Figure 3 presents the prevalence of MSDs among polishers. These results clearly indicate that the existing polishing equipment does not provide any comfort, and there is an urgent need to re-design the existing polishing equipment.

3 Ergonomic Assessment of Existing Polishing Equipment

Digital pictures and video recordings were taken of two polishing workers (*Bagi Dhora,* and *Koloh Tona*) to record the body postures employed as they were performing the polishing activity. The recorded body postures were analyzed with the help of Kinovea® software. Kinovea® is valid and reliable open-access software for postural analysis [11]. With the use of this software, recorded videos were reproduced in slow-motion, and the critical posture of each polisher was determined. The determined critical posture was based on the maximum flexion and deviation of body segments while performing the polishing activity. Figure 4 shows the joint angle acquisition by Kinovea® software.

Due to wide variability in anthropometric measurements, a generic human model of 50th percentile Indian male was used for ergonomic assessment of existing polishing equipment. The body measurements incorporated to build the human model were according to the Indian anthropometric data developed by Chakrabarti [12]. Also, the existing polishing equipment was developed in CATIA V5 software based on the actual dimensions collected from the field (Fig. 5).

To determine the postural discomfort, the postural assessment was performed using the RULA tool [13]. RULA assesses the musculoskeletal risk associated with

Fig. 4 The joint angle detection for handcrafted *Kalash* polishing

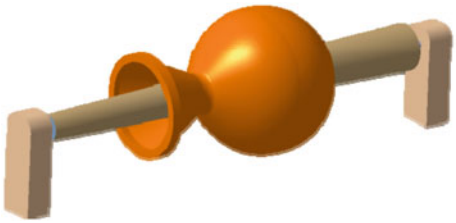
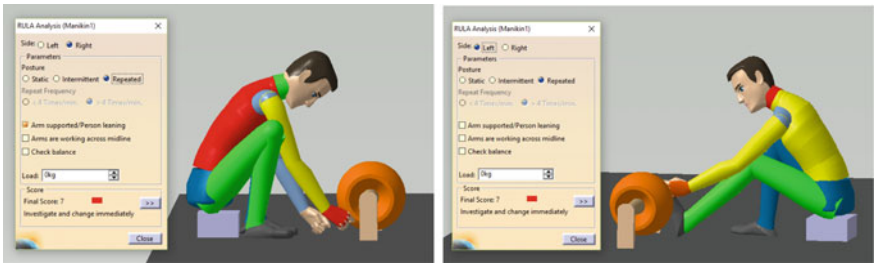


Fig. 5 The CAD model of existing polishing equipment

adopted body postures and gives a final score between 1 and 7. The interaction of digital human with existing polishing equipment was shown in Fig. 6. The results of RULA can be seen from Table 1, which revealed the final RULA score for working posture of polishers (for both *Bagi Dhora,* and *Koloh Tona*) was 7, and required an investigation and immediate change for improvement.



(a) (b)

Fig. 6 Interaction of human model of with existing polishing equipment: **a** Bagi Dhora, **b** Koloh Tona

Table 1 The RULA final score for the existing polishing equipment

	Polishers	RULA score	Risk level	Action level
Existing polishing equipment	Bagi Dhora (50th percentile)	7	Very high	Investigate and change immediately
	Koloh Tona (50th percentile)	7	Very high	Investigate and change immediately

4 Redesign and Evaluation of Existing Polishing Equipment

4.1 Market Survey on Existing Polishing Equipment

A survey was conducted on available handcrafted *Kalash* polishing equipment in the local market. Through this survey, three different types of equipment for *Kalash* polishing were found. In general, this polishing equipment was categorized into three classes (i.e., pedal-operated, pedal-cum-hand operated, and motorized) based on the power input. Figure 7 shows the available polishing equipment in the market. All these available equipment are operated manually and do not influence the artistic value of the craft. However, the polishing workers are not using the equipment at the site. This finding was an interesting aspect during the study. In order to know the reasons for not using the existing equipment by the polishers, an in-depth interview was conducted with an experienced polishing worker. This worker has an experience of 30 years in this field and also a well-known person in this cluster. He explained some of the important factors why they were not using the available polishing equipment. One of the important reasons is that they could not use motorized equipment because there is a lack of continuous electric power supply in their village. Also, the cost

Fig. 7 The polishing equipment available in the market

of the equipment is high, and they could not afford such costly equipment. Most importantly, the space occupied by the equipment is also an important factor as they do not have enough workplace. Based on the initial user feedback, observation of physical working conditions, and market survey, the present study, therefore, carried out the re-design of polishing equipment.

4.2 Design Requirements

For developing solutions to the ergonomic problems faced by workers in the handicraft sector, contextual knowledge is very important. In this context, user requirements for re-designing the existing polishing equipment were collected through a focus group meeting with the handcrafted *Kalash* polishers. In summary, the users mainly expected re-designed polishing equipment to be simple, low-cost, comfortable seating arrangement, occupy less space, simple operation, no electrical power requirement, and also portable.

4.3 Concept Generation and Screening

Based on the requirements of the users, the first author of this study generated four preliminary concepts in the CATIA software. The generated concepts were based on the discussions with the users, ergonomics literature, and brainstorming sessions. Figure 8 shows the four different concepts of polishing equipment. The Pugh chart [14] was used to screen the best concept among four different concepts. Finally, Concept 4 with seat arrangement was selected and finalized by the polishers.

4.4 Final Concept

Figures 9 and 10 show the CAD model and sketch of re-designed polishing equipment, respectively. The re-designed polishing equipment consists of seven major components: frame, stool, holders, arm support, foot-pedal, chain-drive, and collection tray. As mentioned earlier, the awkward working posture is the main problem while performing the polishing operation by polishers. To solve this problem and provide safer work posture, the height-adjustable stool with a pedal operating system was provided. The frame was designed in such a way that it could offer more stability. Further, the holders were designed to accommodate different sizes of *Kalash.* The *Kalash* is placed and locked between the holders with an adjustment screw. Overall, the polishing equipment was designed for comfortable polishing operation without significant bending of the trunk.

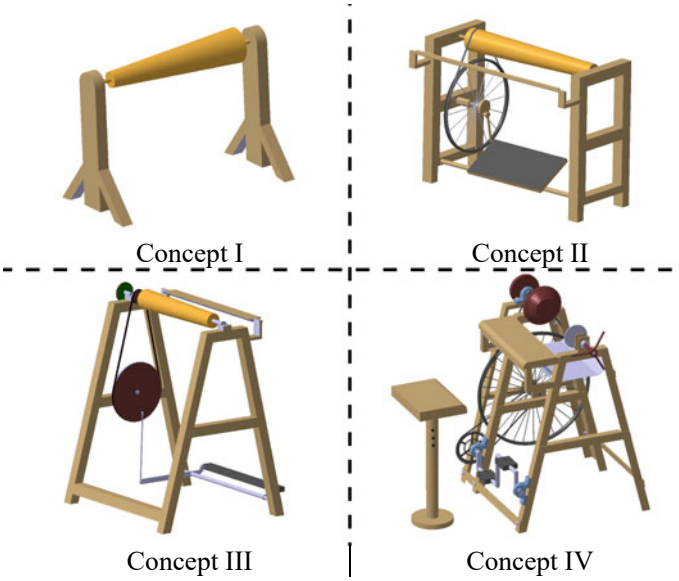
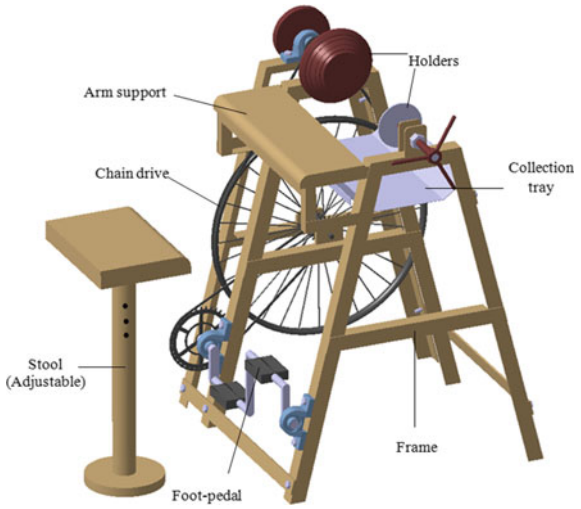


Fig. 8 The generated concepts of re-designed polishing equipment

Fig. 9 The CAD model of re-designed polishing equipment



4.5 Evaluation

RULA tool was used to evaluate the re-designed polishing equipment. Digital human model of 5th Percentile, 50th Percentile, and 95th Percentile were used. These human models were created based on the Indian anthropometric database

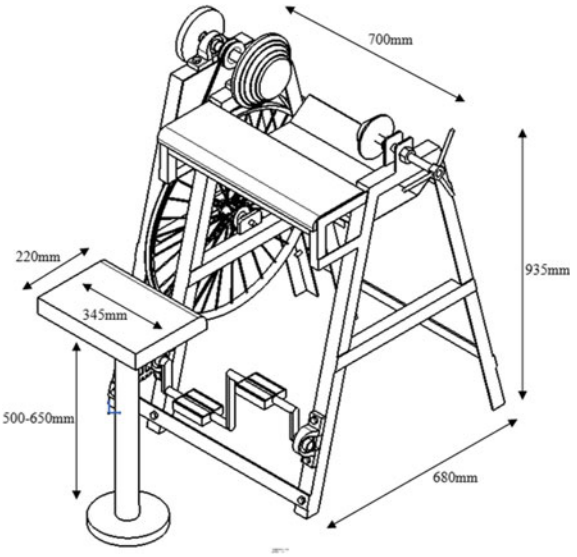


Fig. 10 The sketch of re-designed polishing equipment

[12]. Figure 11 shows the interaction of human model (50th Percentile) with the re-designed polishing equipment. The results of RULA analysis showed that the working posture in re-designed polishing equipment was improved noticeably. The final RULA score was 3 for 5th Percentile, 50th Percentile and 95th Percentile human models, and the risk level was low (Table 2).

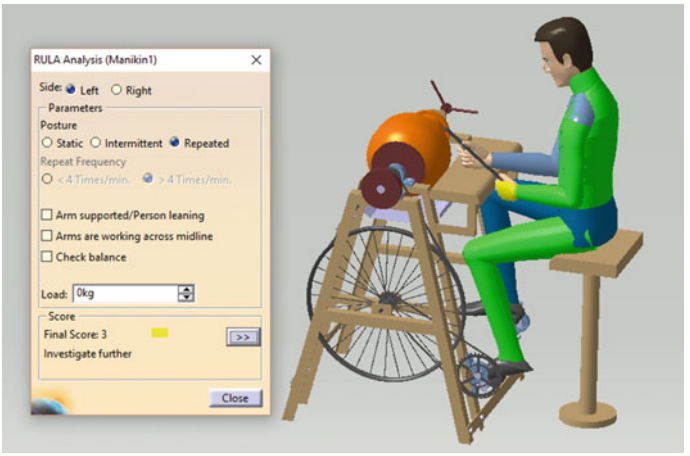


Fig. 11 Interaction of human model (50th percentile) with the re-designed polishing equipment

Table 2 The RULA final score for the re-designed polishing equipment

	Polishers	RULA score	Risk level	Action level
Re-designed polishing equipment	BagiDhora (5th percentile)	3	Low	Investigate further
	BagiDhora (50th percentile)	3	Low	Investigate further
	BagiDhora (95th percentile)	3	Low	Investigate further

5 Discussion

This study on the handcrafted *Kalash* polishing task revealed the prevalence of work-related musculoskeletal disorders among handcrafted *Kalash* polishers. It was found that the disorders in the lower back (75%), upper back (52.5%), and elbows (50%) were most prevalent. The polishers perform the polishing operation in a squatting position for long hours, which increases pressure on intervertebral discs and ultimately leads to pain in the lumbosacral segment of the vertebral column [15]. Therefore, pain in the back region of polishers was mostly due to the frequent trunk bending and twisting during the polishing operation. The ergonomic design of work equipment is one of the recommenced primary prevention measures for abating musculoskeletal problems. Thus, this present study attempted to re-design the existing polishing equipment. Most importantly, when (re)designing work equipment for unorganized sectors in developing countries, contextual knowledge and user needs play central role [4]. In the present study, therefore, initially feedback of actual user was collected. Major importance was given to user needs during design process. Because any complete change in conventional working method may result in rejection by users in long-run. Figure 9 shows the re-designed polishing equipment. The results of RULA analysis showed that the working posture in re-designed polishing equipment was improved noticeably. Therefore, based on these preliminary findings, it is concluded that the ergonomically re-designed polishing equipment in the handcrafted *Kalash* polishing activity could reduce MSDs among polishers and makes the workplace comfortable.

6 Conclusion

This study had demonstrated how the traditional handicraft work equipment in cottage industries can be re-designed by collaborative approach, by paying closer attention to ergonomics. Incorporating ergonomics into re-design of polishing equipment has reduced postural discomfort and manpower utilization from two to one. The improvement in the working posture with re-designed polishing equipment can reduce the physical stain and risk of musculoskeletal disorders among polishers.

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Development of Scale for Assessing Occupational Health Hazards in Post Harvest Activities (OHHPA Scale)

M. Kalita, R. Borah, and N. Bhattacharyya

Abstract Agriculture is the oldest and most important primary occupation compared to other occupations (Kumar and Ratnakar in Indian Res J Extension Educ 11(1):109–112, 2011 [3]). In Assam, more than 70% of farm women are involved in post harvest activities such as threshing, sun-drying, sieving, winnowing, cleaning, seed selection and storage of grains. Post harvest activities are performed by utilizing manual labour and farm women are exposed to variety of health hazards. An attempt was undertaken to develop a scale for assessing occupational health hazards in post harvest activities (OHHPA scale). Survey method was conducted on three hundred farm women of six different villages of Jorhat district, Assam. Women samples were selected at three stages viz—60 respondents for item analysis and testing reliability and 300 women samples for administering the developed scale. Personal and demographic characteristics of the respondents revealed that 100% were literate and two third of the respondents belonged to nuclear families. Eighty two per cent of the respondents were marginal farmers who have 1 acre of land for paddy cultivation. Majority of the respondents (88%) were in the age group of 30–40 years. Biological, physical, accidental and environmental hazards were common among Assamese farm women except chemical hazards. Respondents in the 'high' incidences category was found to be more than 38% who were suffering from all types of hazards where as 'severe' incidences category were nil in the study area. The findings also showed that 58% respondents were in the category of 'high' incidence of hazards in post harvest activities.

Keywords Agriculture · Occupation · Health hazards · Post harvest activity · Proneness

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1 Introduction

Agriculture is the oldest and most important primary occupation as compared to other occupations for all human beings [3]. In Assam, more than 70% of farm women are involved in post harvest activities such as threshing, sun-drying, sieving, winnowing, cleaning, seed selection, storage products, grading and packing for sale. Post harvest activities are performed by utilizing manual labour and farm women are exposed to variety of health hazards that are harmful to their health and well-being. Health has been defined as a complete state of physical, mental and social well being of an individual [4]. The farm women are at increased risk for occupational hazards, musculoskeletal disorders, reproductive disorders, dermatological conditions, infectious diseases, hearing loss, stress and lung diseases [6]. Occupational hazards and health issues can rise at any phase of agricultural production such as sowing, harvesting, packing, storage and transportation. The occupational health hazards may be of different types such as biological, physical, chemical, accidental and environmental. The occurrences of physical hazards are due to heavy physical workload or ergonomically poor working conditions, lack of training in agriculture [10]. Biological hazards are due to close contact with animals and plants while performing agricultural activity. The causes of accidental hazards are the use of non-ergonomically designed or hazardous agricultural tools and equipments, non-availability of personal protective equipment etc. Working under hot and humid conditions, noise, vibration etc. are the major causes of occurring environmental hazards. A study on respiratory problems were reported by 65–70% of respondents during threshing and harvesting operation. Tractor and thresher accidents and temporary noise-induced occupational hearing loss are among the mechanical hazards to which only few workers were exposed [9]. In Assam farm women are suffering from all types of health hazards except chemical hazards while performing post harvest activities. An attempt was undertaken to develop a scale for assessing occupational health hazards in post harvest activities (OHHPA scale).

2 Methodology

This section includes selection of study area, sampling and data collection procedures as well as data analysis for construction of attitude scale.

2.1 Selection of the District, Blocks and Villages and Sample for the Study

The present study was conducted on Jorhat subdivision of Jorhat district of Assam. Three blocks and from each block two villages were selected randomly and there

by all together six villages and 300 farm women were selected proportionately for assessing health hazards faced by farm women in performing post harvest activities. The scale was developed by using summated rating method [5]. After evaluating by experts a final list was made and administered on subjects for 'item analysis'. For item analysis '*t*' value of each individual statement was calculated. Statement were divided in to five categories *viz.*—'strongly agree', 'agree', 'undecided', 'disagree' and 'strongly disagree' and with a score of 5, 4, 3, 2, and 1 respectively. Statements with highest 't'-value were selected for scale construction.

The critical ratio, that is the '*t*' value which is a measure of the extent to which a given statement differentiates between the high and low groups of the respondents for each statements was calculated by using the formula [1].

The '*t*' values were calculated for each item. The significance level of '*t*' value is 1.75. The calculated '*t*' values were found to be distributed between 1.81 and 12.31. The statements with '*t*' values of 1.75 and above were considered for final inclusion. Finally 20 positive and 20 negative statements with highest '*t*' values were selected for the final scale as they were differentiate between highest and lowest groups.

2.2 Standardization of the Scale

For standardization of the scale validity and reliability was ascertained. Reliability of the scale was assessed by applying two different two methods—i.e. split-half technique and test–retest method. The final set of the 40 statements, which represent the health hazards of farm women towards occupational health hazards in post harvest activities, was administered on five-point continuum to a fresh group of 60 women farmers, which were not included in the final sample. After a period of 15 days the scale was again administered to the same respondents and thus two sets of scores were obtained. The correlation coefficient for both the sets was worked out by using Karl Pearson's coefficient of correlation and significance level of '*r*' is **−1 to +1**. Value of −1 signifies strong negative correlation while +1 indicates strong positive correlation.

The calculated '*r*' value was 0.97 which is significant indicating the scale was highly suitable for administration to the women farmers as the scale was stable and dependable in its measurement. In the split half method calculated '*r*' value was found to be 0.96 which was significant indicating high internal consistency of scale constructed for the study.

The tool was standardized by reliability and validity test. Data was collected from 300 non sample subjects to assess hazard proneness.

2.3 Validity of the Scale

The scale satisfied all possible statements that could be made about health hazards of farm women, was formulated from the standards and also in consultation with experts who had knowledge on OHHPA. This ensures high content validity of the developed scale. The reliability and validity of the scale indicates precision and consistency of the results [3].

2.4 Final Scale

The final scale consists of 40 items which represents various aspects of occupational health hazards in post harvest activities viz., biological, physical, accidental and environmental hazards.

2.5 Administration of the Scale

The final scale was administered on 300 subjects or respondents to assess hazard proneness.

After analysis of collected data, the resultant scores were compared with categories of score in Table 1.

3 Results and Discussion

The working conditions of female agricultural workers in India are alarming. The hazards faced by them in agriculture calls for immediate attention of planners and policy makers for remedial measures. There was no scale available to measure occupational health hazards of farm women in post harvest activities. According to the International Labour Organization [2], the agricultural sector is one of the most hazardous to health all over the world. It has several characteristics which are risky for health. Farm women are expose to hot and cold weather, close contact

Table 1 Categories of hazard proneness according to sores

Score range	Hazard proneness
40–80	Low incidence of hazards
81–120	Moderate incidence of hazards
121–160	High incidence of hazards
161–200	Severe incidence of hazard

with animals and plants, extensive use of chemical and biological products, adoption of poor working postures and lengthy hours, carrying heavy loads and use of hazardous/defective agricultural tools and machinery.

3.1 Assessment of Different Types of Occupational Health Hazards of Farm Women in Post Harvest Activities (OHHPA)

Survey method was used to elicit the information on the socio-economic and health hazards in post harvest activities. For assessing occupational health hazards in post harvest activities (OHHPA) of farm women, a scale was developed. The developed scale was administered on 300 farm women to assess hazard proneness in post harvest activities. Personal and demographic characteristics of the respondents revealed that 100% were literate and two third of the respondents belonged to nuclear families. Nearly 38% respondents were from upper caste, which was followed by more other backward castes (35%) and lower castes (27%). Annual Income of the respondents farm families were ranging from Rs. 85,000/- to Rs. 400,000/-. Majority of the respondents (82%) belonged to marginal farmers having 1 acre of land for paddy cultivation. Majority of the respondents (88%) were in the age group of 30–40 years. Distributions of animals were found very common in the studied households. More than 60% of households cultivated paddy for their livelihood. All the studied households found to be storing paddy after harvesting either for their own consumption or for sale when price rises. Cent per cent respondents (100%) farm women participated in post harvest activities especially in storage of paddy. Traditional technologies were found to be used by farm women for performing post harvest activities The study revealed that technologies used for paddy cultivation were plastic bags, serrated sickle (*Kachi*) for harvesting, pointed bamboo stick (*Ukhon*) for separation of paddy straw, winnower (*Kula*) for winnowing, siever (*Chaloni*) for cleaning, spreading tool (*Kurhuna*) for sun drying, bamboo basket (*Pacchi*) for carrying paddy grains, *bhoral/mer/duly* etc. for storing paddy grains.

Further observations were made to assess different types of health hazards faced by farm women in post harvest activities. Data on Fig. 1 revealed that biological, physical, accidental and environmental hazards were common among Assamese farm women except chemical hazards. Respondents in the 'high' incidences category was found to be more than 38% who were suffering from all types of hazards where as 'severe' incidences category were nil in the study area.

Biological hazards: Biological hazards which are most commonly occurs in farm women in post harvest activities included cuts or wound, skin allergy, respiratory diseases, irritation of eyes, sour throat etc. due to dust particles of paddy straw and insect bites. Further analysis of data revealed that 58% respondents were in 'high' incidence of biological hazards followed by 42% 'low' incidence of hazards in post harvest activities (Fig. 1). Occurrences of 'moderate' and 'severe' incidences of

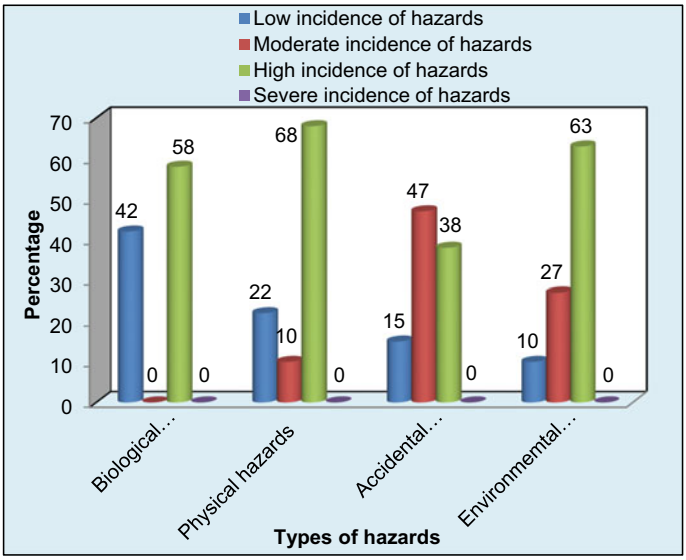

Fig. 1 Different types of health hazards faced by farm women in post harvest activities

hazards were nil. Study on biological hazards was conducted and found that about 25% of respondents reported injury due to farm implements, falls, insect and snake bite [9].

Physical hazards: The findings on the physical hazards revealed that 68% of the farm women faced 'high' incidence followed by 22% 'low' and only a very meager per cent that is 10% suffered 'moderate' incidences of physical hazards (Fig. 1). The causes of physical hazards may be due to adoption of bending posture, carrying heavy loads, repetitive nature of work and use of bare hands in post harvest activities. Similar opinion was observed and concluded that the factors causing physical health problems are longer work duration, strenuous posture at work, repetitious work movements, overwork, unsuitable work conditions, unsuitable equipments, unhygienic environment etc. [8].

Accidental hazards: As regards to assessment of accidental hazards it was observed from the Fig. 1 that occurrence of accidental hazards were less as compared to biological, physical and environmental hazards. About 47% respondent farm women faced 'moderate' followed by 'high' and 'low' incidence of accidental hazards in post harvest activities. The most common accidental hazards among farm women are injury, broken or bleeding of nails due to stones, sticks and pebbles mixed with the grains, abdominal pains for adoption of bending posture and miscarriage and menstrual disorders as a result of lifting heavy loads. The use of personal protective equipment was not common among the Assamese farm women while performing post harvest activities. Similar study on accidental hazards was conducted found that about 25% of respondents reported injury due to farm implements [9].

Environmental hazards: Environmental hazards of farm women in post harvest activities are pain or cramps, indigestion, eye strain, watering of eyes, blurred vision or vision problem, loss of hearing capacity, temporary deafness, headaches and faintness due to working under hot, humid, noisy and inadequate lighting conditions. From the Fig. 1 it was apparent that 63% respondents belonged to 'high' incidence of hazards followed by 27% 'moderate' and 10% 'low' incidences of environmental hazards during post harvest operation. Occurrences of environmental hazards were due to working under hot, humid and poor lighting condition. The farm women working in hot climate with extreme temperature also created problems to approximately 80% of the respondents of agricultural workers [9].

Thus agricultural workers involved in post harvest activities confronted various biological, physical, accidental and environmental hazards in performing post harvest activities.

3.2 Assessment of Occupational Health Hazards in Post Harvest Activities (OHHPA) of Farm Women

Further investigation was made to assess health hazards of farm women in post harvest activities as a whole. The findings also showed that 58% respondents were in the category of 'high' incidence followed by 'Moderate' incidence (29%) and 'Low' incidence of hazards (13%) of hazards in post harvest activities (Fig. 2). It was also observed that 'Severe' incidences of hazards were found to be nil among the respondents of the study area. Various bad health effects are the results of the cause that insufficient base line anthropometric data is available before designing any new technology [7]. The hazards faced by farm women need ergonomic intervention as a remedial measure as soon as possible. Similar study was conducted in Udaipur and they opined that most of the women were in the category of 'High' incidence of hazards [7]. The high scores in occupational health hazards indicate that the working

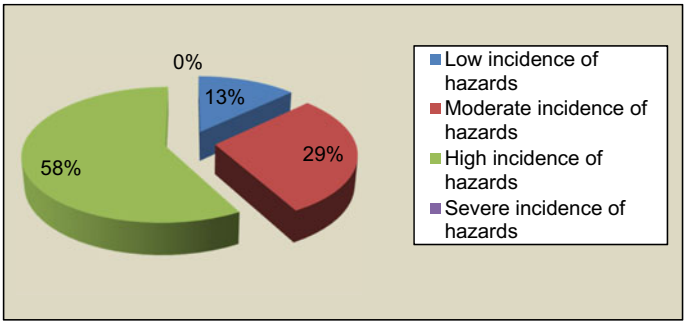

Fig. 2 Distribution of the respondent's farm women according to hazard proneness in post harvest activities

conditions of female agricultural worker in India are alarming. The hazards faced by them in agriculture calls for immediate attention of planners and policy makers for remedial measures.

4 Conclusion

From the findings of the study it was concluded that there is a strong need to motivate and aware farm women towards different occupational health hazards in post harvest activities and its alleviation. Few conclusions are drawn with an intension to minimize the health hazards and enhance comfort and well being of farm women. Occupational health hazards in agricultural activities in general and particularly occupational health hazards related to post harvest activities are in new stage in India. For development of health and well being of farm women entirely depends on adoption of best practices which is also depends on the attitude of farm women. This scale can be used to measure the health hazards of women farmers' beyond the study area with suitable modifications. From the finding of the study it was apparent that most of the women (58%) were in the category of 'High' incidence of hazards. Such a high score indicate that the working condition of women farmers in post harvest activities in Assam is alarming. The hazards faced by them calls for immediate attention of planners and policy makers for remedial measures to reduce the hazards at work.

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Ergonomic Analysis of Manual Activities Among Dairy Farm Workers: A Literature Review

Umesh Gurnani, Sanjay Kumar Singh, Manoj Kumar Sain, and M. L. Meena

Abstract Agriculture and dairy farming work involves several work related health issues. The work related health problems are more prominent in developing countries like India. Among these health issues, the most critical are musculoskeletal disorders (MSDs) which are most widespread to an epidemic extent. The research aims to scientifically examine the most significant hazardous factors causing MSDs and propose the possible ergonomic solutions. The literature was searched from different databases using different search criteria. The review was restricted to physical health issues among dairy farm workers developed due to heavy load and repetitive tasks in awkward posture. Literature reveal that MSDs creates more prolonged effect on the workforce of developing countries compared to developed counties because of the acquaintance to mechanized dairy operations in developed countries. Dairy farming includes different manual and repetitive activities like milking, feeding cattle, manure cleaning and medical operations. Continuous repetitive activities in uncomfortable postures such as bending, kneeling as well as the use of inappropriate tool design results in the emergence of different MSDs including lower back problems. Prevalence of MSDs and lower back problems was found to be significant which needs a proper ergonomic intervention. The safety and health measures in agriculture and dairy farming business need a global reformulation to enhance awareness on injuries arising and chronic MSDs.

Keywords Dairy farming · Musculoskeletal disorders · Manual material handling · ergonomic intervention

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1 Introduction

Dairy farming is a significant division of agriculture for thousands of years. Primarily, milk and dairy products were consumed in local market for domestic purposes but later on with the developing countries and growing population; mass production became mandatory with improved quality of milk for open consumption worldwide. Milk production is one of the important nutritional factors for the rural economy in India. In India, 17% of the total output from agriculture comes from dairy sector, as a result of which dairy sector grabs first position of the total agriculture production followed by the production of rice with 14.4% and wheat by 8.7% as reported by Central Statistics Office India, 2001 [1]. Since 1970, India's milk production has grown by an average of nearly 5% per year and in 2000 became the largest milk-producing country in the world. Currently India accounts for 1/5th of the dairy production across the world [2]. India has already reached a production of 198 MT in 2019–20 [3].

Dairy sector contributes about 25% of India's National income and the agriculture sector as a whole employs more than 60% of the workforce in India. The dairy industry alone provides employment to about 85 lakh of population on annual basis out of which 71% are women. 92% of rural households are employed in different tasks related to dairy industry [4].

With the innovation of mechanized milking system and the easy availability of electrical power, the volume of milk production significantly improved. As studied Automatic milking systems (AMS) can increase the milk production by 10–12% and also reduce the labor by around 18%. The annual milk production per cow has tripled from 2404 kg in 1953 to 9049 kg in 2007 in United States [5]. Many past researches have concluded the increase in milk production of 2–12% by cows milking 2–3 times per day using AMS compared to the Conventional Milking System (CMS) done 2 times a day [6].

Due to technical improvements, the development of milking pipelines helped to get rid of the manual workload associated with material handling of heavy buckets of milk.

The investment required for farm mechanization sector is estimated to be 76,991.78 Crores, which is near about 3% of including all the other priority sectors with a tentative projection amount of 2,868,753.65 Crores (NABARD, Dec-2018).

With the establishment of the mechanized dairy setup in the twentieth century the physical risk factors related to manual work might have reduced but have struck up new tasks for dairy workers. High-tech advancements like the establishment of milk parlor may have reduced exposure to the uncomfortable trunk and lower extremity postures but have also created an exposure to ergonomic risk factors related to upper extremity of body and neck related musculoskeletal disorders (MSDs). However, the dairy farming in most of the developing countries like India is not fully mechanized and most of the work is performed manually. The manual activities in dairy farming are: milking, feeding of animals, manure handling, medical treatment of animals and green fodder cutting.

The review paper aims to highlights the occupational health problems among dairy farm workers and various risk factors.

2 Research Methodology

To find the effect of ergonomic intervention on dairy and agricultural work various research papers are selected on the different research criteria. The research methodology applied in present study is following:

Step-I: **Collection of Information**: The articles were searched from e-database of Scopus, Web of Science, PubMed and Google Scholar for last 15 years with relevant topic in review as well as new research in the same area.

Step-II: **Short listing the most relevant research work**: Based the abstract, results and conclusion the relevant research articles were filtered, shortlisted and considered which had focused on physical problems, human body disorders faced in the field of agriculture and dairy farming.

Step-III: **Data Extraction**: In general, more than 100 research papers were selected for dairy work review based on the keywords like ergonomic activity in the dairy industry, MSD in dairy works, different jobs involved in dairy work, ergonomic intervention. The survey methods, sample size, survey questionnaire, were also identified during the review process. A summary sheet was being prepared comprising of various activities related to dairy farming, physical body disorders faced by manual farm workers and the factors which are the sources of musculoskeletal disorders in human beings.

3 Different Activities in Dairy Farm

In most of the dairy farming locations, the work is almost the same but few tasks are different depending on dairy requirements. In Table 1, the main steps are involved used in dairy farming work at present. In most of the research papers, these jobs are identified to find the impact on dairy workers in the respect of MSD problems. Like Dairy farming, in agricultural work different steps are required to complete the entire work. These jobs are responsible for the MSD issues in workers. In Dairy farming, green fodder cultivation is required, so it is an agricultural activity. Various researchers work on the effect of ergonomics on workers during these activities. The main tasks involved in agricultural activities are present in Table 1.

Table 1 Different jobs involved in dairy farming works

S. No.	Working steps	Description
1	Green fodder cutting	• Green fodder is cut by a manual process on a daily basis
2	Green fodder Fine cutting	• Material handling of green food to cutting facility • Fine cutting of fodder done manually on a daily basis
3	Dry fodder mixing	• Mix both foods by manual process • Moving fodder to animal shed manually
4	Fodder circulation	• Manual food circulation
5	Daily work in cowshed	• Washing of utensils daily two times which are used in farm • Washing of cattle at least once a day
6	Milking process	• Perform milking of cows daily two times to fill around 40 drum containers with milk and move them manually while distribution of milk in containers
7	Milk packing	• Milk is packed daily once
8	Milk delivery	• Material handling of milk containers one a day in the mode of transport
9	Harvesting	• Major farm harvesting work is completed by manually
10	Material handling/load carrying	• Material handling activities are the main source of MSD in workers There are no proper types of equipments available for this task especially in developing countries
11	Pruning	• This task has a major job safety issues because there is a direct risk to human body. Very less technological improvement is recorded for small agricultural activities
12	Planting	• Major ergonomic disorders are recorded by researchers due to planting activity in especially in developing countries
13	Digging	• Ergonomical disorders are generated and reported by many researchers especially in women workers while bending, kneeling and applying force for this operation
14	Peeling	• Ergonomical disorders are generated and reported by many researchers especially in women workers and low height male workers due to their frequent body stretching
15	Sorting	• Very less MSDs are possible in this activity
16	Weeding	• Manual weed removal can create MSD issues in workers

4 Outcomes of Literature Review

A few investigations have indicated that cultivating is a truly seeking farm duty that can result in musculoskeletal problems (MSDs). The studies convey that MSD is basic among dairy laborers, particularly in the lower back areas, shoulders, wrists and knees. Due to an absence of dependable and acknowledged estimation of MSDs, analysts are compelled to depend on self-analyzed musculoskeletal manifestations (MSS) as a pointer of MSDs. Dairy ranchers in Ireland, Australia and Sweden and recruited laborers have been accounted for studies including the commonness of MSS and MSDs among them. Specialists, who assessed over 80% of Swedish dairy ranchers and employed laborers, the gripe of MSS in a period of a year,. The dominance of MSS in a body part chosen randomly was roughly approx 85% among Swedish dairy ranchers and approx. 80% among recruited laborers. Musculoskeletal side effects were essentially situated in the lower back (approx. 50%), shoulders (approx. 40%), and in knees (approx. 35%), with lower prevalence in the neck (approx. 30%), hand/wrists (approx. 20%), and hips (approx. 23%) among ranchers and laborers. By and large, females as a rule report altogether high prevalence of MSS in body parts (approx. 76%) also, particularly in the hands/wrists (approx. 55%) compared to men. Further, contemplates have additionally found that females account for essentially higher inconvenience due to tedious and repetitive work compared to male colleagues. Amongst the Irish dairy ranchers, 30% of them revealed having low back torment, 22% revealed neck and shoulder torment, and 10% agreed for strain in hips. Larger group sizes, extraordinary parlor conditions and draining strategies, and social contrasts that impact self-detailing of side effects make the examinations between dairy examines troublesome. These components may have much of a critical impact on MSS with parlor laborers on homesteads with developing crowd size. Somewhere in the range of 2005 and 2009, US dairy ranches with less than 500 bovines declined.

Boyle et al. (2011) announced draining is the best expansion in danger among dairy ranchers in the Midwest of the United States. Among little crowd (<500) US dairy ranches, hours of draining were discovered to be related to elbow syndrome. Consistent with this discovery, Pinzke and Jakob [7] detailed a relationship between elbow MSS in female milkers and the number of cows drained. Moreover, the count of dairy animals drained in the parlor was related to elbow MSS among female milkers. Utilizing polls, Kolstrup and Ssali [8] examined six dairy errands: machine draining, treatment of feed, compost expulsion, taking care of, litter throwing and cleanliness of parlor. They discovered the draining through the machine as the most destructive tasks. Results recommended that monotonous movement wounds (RMIs, for example, CTS might be a critical well-being challenge for huge group parlor laborers. Kaewdok et al. [9] used a convenient sampling method with 481 old farmers from a province in Thailand to determine the occurrence of MSDs with lower extremities (65.4%), lower back (42.6%) and shoulders (29.9%) as Agriculture occupational illness. Moreover, Stål et al. distinguished that pronator disorder may likewise be a huge well being challenge for dairy parlor laborers. Karttunen and Rautiainen [22]

directed a review partner study to assess the rate and hazard factors for remunerated word related wounds and illnesses in Finnish horticulture. Discoveries recommend that dairy ranchers have a 2.2 relative danger of injury contrasted to oat crop ranchers. Ghafari et al. [10] focused on hygiene-related study regarding the work-related health of farmworkers in Iran and categorized the occupational risks as chemical, physical, and biological hazards. The results analyzed 40% of injuries related to mechanical and environmental factors.

Omoniyi et al. [11] carried out a research study on the feasibility of exoskeleton use in Canadian livestock farm and the effect of exoskeleton use on overlapping themes of 'safety', 'comfort', 'jobs and timing', 'health', 'mobility', 'ease of use', and 'productivity'. The research was conducted through structured interviews with farm workers which showed diversity in their approach of exoskeleton performance on conditions of comfort, safety, and productivity. Kang et al. [12] worked on identifying risk analysis for MSDs among Korean Farmers using multiple logistic regression analysis on the job-related disorder and injury survey data of 16,113 participants and concluded that functioning in animal husbandry extensively amplified the risk of injury in upper extremities, compared to irrigation farming (odds ratio: 1.837, 95% confidence interval: 1.130–2.987).

Gadhavi and Shukla [13] conducted research on farmers of Gujrat on the prevalence of work-related MSDs by including the participation of 947 farmers with all age groups varying from 18 to 70 years. Different farm activities which involve muscular movements like forward bending, twisting and prolonged body contact with driving machinery along with frequent heavy load carrying and improper guidance result in heavy body stresses that affect the spinal disc making them prone to injury. Repetitive squatting involves eccentric contraction of quadriceps muscle leading to non-uniform lengthening of body muscles or other ultra-structural abnormalities. Younesi et al. [14] used the concept of Agricultural Whole-Body Assessment (AWBA) to evaluate working postures and to determine the level of discomfort and MSDs disorder through a body map questionnaire and SPSS software version 16, using t-test and Mann–Whitney test conducted on 135 survey participants. The study was specifically carried out for fruit pickers in Iran which concluded at the shift towards mechanized agriculture being the highest priority among major potential interventions. Mucci et al. [15] reviewed the health hazards in agriculture using 951 references and focussed on deformations in upper extremities and upper limbs could be permanent and the victims are most affected in the age group of 20–45 years or even younger sometimes. The major concern of these hazards in upper extremities is due to the recurring use of hand tools like sickle, axe, spade, handsaw and hoes and machines like grain augers, power take-off, corn pickers, and wheat thresher used in Agro farming mainly constrained to the Italian provinces.

5 Results

Some important outcomes of literature review are summarized in Table 2.

After literature review, it is found that MSDs are common among manual dairy farm workers in lower back, spinal area, upper extremities, and upper limbs due to their rigorous and repetitive tasks which involve continuous lifting, load carrying, bending, kneeling, and twisting of muscles in various dairy operations throughout the day. There are certain tasks which involve rigorous movements of same muscles over and over again thereby developing a strain in those muscles leading to injury or stressed deformation. The body postures are more stressful depending on surface gradient and the stress also increases with increase in mass of the carrying load. Various operations performed by farm workers in day to day work result in different kind of musculoskeletal disorders. Very limited research work is available on the ergonomic development of agriculture and dairy workers who work in uneven environmental conditions and studies reveal that making significant changes in the workstation design can help us to heal the occupational health issues of manual farm workers.

Table 2 Key findings of literature review

References	Type of job	Major issue present in job	Techniques used by researcher
Azim Karimi et al. [16]	Dairy farming	MSD during milking process	• Cornell Musculoskeletal Discomfort Questionnaire [CMDQ], Quick Exposure Check (QEC) were used as baseline assessment of MSDs in 48 dairy farmers • Neck, shoulder and lower back were the common discomfort areas in all farm workers • A well scheduled exercise programme, ergonomics training, optimized work rest routine, revised task procedure with better instruments • The effectiveness of multicomponent intervention was high and resulted in improvements in frequency, severity and exposure risks of MSDs

(continued)

Table 2 (continued)

References	Type of job	Major issue present in job	Techniques used by researcher
Chapman et al. [17]	Dairy farming	Injuries, and musculoskeletal discomfort	• Mail questionnaires of 20 min were framed for individuals aged 6–18 years for dairy farmers of Wisconsin • Analysis of time spends and the risk borne by any particular age groups in different activities of dairy farming compared to other agricultural activities • Six nonfatal injuries were reported in individuals who required medical attention
Douphrate et al. [18]	Dairy farming	Workers injury and musculoskeletal discomfort	• Nine milk parlors were brought under observation for testing purpose • Battery powered portable logger Virtual Corset inclinometer device was used on each rotary worker to calculate the min and max angle during milking and frequency of operating at that angle • Workers have high risk occupation due to intensive work of shoulder, movement velocity and repetition

(continued)

Table 2 (continued)

References	Type of job	Major issue present in job	Techniques used by researcher
Douphrate et al. [19]	Dairy Farming	Work risk during Machine milking	• Survey was conducted on 11 experienced herd parlor workers • Muscular movement during milking was calculated using electromyography (EMG) on 6 different designed units • Milking unit design can reduce the muscular movement in upper extremities and in turn reduce fatigue and increase productivity
Björn Gunnar Hansen et al., 2020	Dairy farming	Automatic milking Systems (AMS) comfort and satisfaction among farm workers	• Web administered questionnaire response was taken from 1700 workers each with AMS and CMS • An SEM (structured equation model) was framed to calculate the work satisfaction of survey members at different levels • Increased income, better cowshed, family farming increase job satisfaction and high education, being male, loneness and health worries reduce work satisfaction irrespective of AMS or CMS system

(continued)

Table 2 (continued)

References	Type of job	Major issue present in job	Techniques used by researcher
Hwang et al. [20]	Dairy farming	Posture evaluations in loose system dairy work	• Tethering system and loose housing system dairy operations were studied at different farms • Postural load and strain calculation was done for all standing, sitting, kneeling and bending activities in both systems using EMG • Tethering system imposed more stress on trunks and heads of farmers compared to loose housing system due to difference in working height and distance of workstation design
Masci et al. [21]	Dairy farming	Bio-mechanical risk analysis of upper limb	• 40 male dairy workers were chosen from three common milk parlors for survey • Biomechanical overload study was done on upper limb to study wrist and hand disorders • Workstation characteristics, work organization, milking routine are most common risk outcomes

(continued)

Table 2 (continued)

References	Type of job	Major issue present in job	Techniques used by researcher
Kang et al. [12]	Greenhouse cultivation and animal husbandry	Understand occupational specific mechanism and developing appropriate prevention strategies	• 400 villages with different kind of agricultural work were sample surveyed with male and female participants • Multiple logistic regression analysis were performed to calculate risk of MSDs • Effect of age, sex and different farm working conditions determine the level of MSDs in upper extremities, lower extremities and back
Gadhavi and Shukla [13]	Agro farmers in Gujrat	Body's most prevalent part in work-related MSDs is lower back in most of the occupations	• 947 workers were selected randomly to face self developed interview questionnaire survey • MSDs were divided in 9 different parts of body in the survey questionnaire and studied • MSDs are most prominent in lower back, knee and shoulder and neck as per the results
Mucci et al. [15]	Agro farming	MSDs in upper extremities and upper limbs	• 951 reference articles related to agriculture were filtered and studied • Most common type of injuries in agriculture workers are related to upper extremities, upper limbs and hands

6 Conclusion

Since ergonomics aims to fit the task to the person, this study was focused on ergonomic analysis to study the risk factors in the dairy industry.. The study could investigate the most significant ergonomics risk factors that can create a possibility of injury to musculoskeletal system. These risk factors are repetitive working in uncomfortable postures, vibration and force which may come from lifting, material handling, gripping, pushing or pulling, kneeling, bending postures for prolonged duration. The stresses generated in muscles due to continuous working in awkward static positions increases the probability of injury. There is a very less research available where using a certain methodology and input data related to body posture, amount of load carried and duration of manual material handling can determine worker's biomechanical load and the likelihood of developing MSDs. Agriculture and Dairy Farming industries provide huge employment opportunities to the workers but the occupational health aspects in their working environment are underrated and along with MSDs they are also prone to inhalation of noxious materials which result in respiratory hazards, eye problems and skin related complaints. There is a scope of good research in this area by improving the working environmental conditions of manual farm workers using modern techniques and ergonomic intervention thereby eliminating the hazards, risks along with musculoskeletal disorders. Low back pain followed by upper back, knee, shoulder, neck, elbow, hip, wrist, hand, ankle and foot are the most common parts with high prevalence of MSDs. The effect of age, sex and different types of working conditions in farms determine the level of MSDs in upper extremities, lower extremities and back. The study reveals that dairy farmers are more prone to body disorders compared to agro-farmers. The investigation also reveals that milking routine, workstation characteristics, automation and mechanization used in farms also determines the level of musculoskeletal disorders and other health aspects in a dairy organization. Future studies should give more of attention on determining how specific dairy tasks contribute to MSDs in different body parts leading to prolonged injuries many a times. There is also a good future scope of research in calculation of muscular fatigue from dairy farm activities and the limits of material handling capacity among workers of small and medium scale dairy industries.

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Digitizing the Street Vending Market

Abhishek Singh, Pratul Chandra Kalita, Gurdeep Singh, and Raksha Singh

Abstract Fuelled and pumped by liberalization policy and incoming Foreign Direct Investment (FDI) funds, the Indian market's retail sector has become highly dynamic. The organized retail backed by technology and infrastructure is posing a great challenge to unorganized retail. Unorganized retail is not able to compete with them due to the paucity of funds and infrastructure. It is severely affecting the social structure and occupational well-being of the unorganized retailers, especially the street vendors. There lies a dire need to equip them with modern technology-enriched low-cost design interventions that may empower them to compete with the organized retail. Several researchers have advocated the need of designing and developing context-specific design interventions as a mitigating solution. In this research, the authors have proposed a low-cost vending cart that is enabled with a system for automating the inventory and billing facility to digitize the street vending market. It can empower the street vendors with technology-rich features installed within their existing infrastructure to sustain and dwell well in modern cut-throat competition. Its market potential, probable user-acceptance, and enablement aspects have been tested and accumulated using the System Usability Scale (SUS) and securing Intellectual Property Rights (IPR) by receiving patent grants. This paper highlights the developed innovative intervention with its working details. It may act as a ready reckoner and potential literature source for the researchers/entrepreneurs/social scientists to develop similar kinds of innovative solutions to equip the lower strata population and the bottom of the pyramid for their betterment and occupational well-being.

Keywords Online street market · Digital unorganized sector · Low-cost cloud marketing · Design intervention · Human-centered design · Occupational well-being

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1 Introduction

In India, the advent of liberalization policy implemented by Indian policymakers in 1991 opened the gates for the global market. It attracted Foreign Direct Investment (FDI), and with its increase, the share of organized retails increased simultaneously. Further, with the introduction of online shopping formats in recent years, the share of organized retails started to grow multiple folds every year. However, within this development happening all around, the unorganized sector that provides the highest employment opportunities to the Indian population got neglected and came under direct threat. Retailing in India accounts for over 10% of the country's GDP and 8% of total employment. The unorganized retail sector dominates the Indian retail market; it forms around 90% of the total Indian retail market [1]. Currently, the ever-increasing organized sector poses a great challenge and adverse effect on the working population engaged in the unorganized sector. In this context, it is pertinent to understand the linkages between the Indian economy, its sectors, market scenario, etc., to empathize with the miseries of the unorganized sector's working population.

Typically, 'Retail' is defined as the sale of goods in relatively small quantities in public for use or consumption and not for resale. This type of earning does not require any prior qualification or firsthand experience to start up. Depending on the liquidity available to the person, one can start their own retail. Such marginal retailers purchase the products in bulk to enjoy volume discounts and further sell these in the nearby localities at the Maximum Retail Price (MRP) to earn their profits. Generally, the volume discounts available upon bulk purchasing are their margin of earnings. Additionally, purchasing a product that is available in bulk at some location and selling it in localities where it is scarce at a higher price is another way to see this transaction. In the current scenario, the three types of retails exist in modern-day market setup viz. organized retails, unorganized retail, and E-tails. The retail setup employing less than ten employees is categorized as an unorganized retail/sector. The setups engaging more than ten employees are categorized as organized retails. E-tail is the modern setup of selling products online with the help of the internet, and it is becoming quite popular with the modern youth and is rapidly penetrating tier II and tier III cities squeezing the unorganized retail sector [1, 2].

In 2017, India Brand Equity Foundation (IBEF) predicted that by the year 2020, the unorganized retail would be crunched by 3 percent to provide room for organized retails to expand its share in the Indian retail market (Fig. 1) [2]. It will reduce the share of unorganized retail from 93 to 90% within a short span of mere three years. Similarly, in 2019, Business-Standard predicted that the share of organized retail space would touch 19% by 2020 in India [3]. These reports show that the government policies are favorable towards organized retails, and they had severely hit unorganized retail. It had an adverse social impact on unorganized retailers.

The studies by other researchers also indicated the same trends and adversities. While studying the impact of malls on small shops and hawkers, Kalhan reported a 20 percent drop in unorganized retail sales due to organized retail entry [4]. Edward and Atham, in their study on the impact of supermarkets on unorganized retail, reported

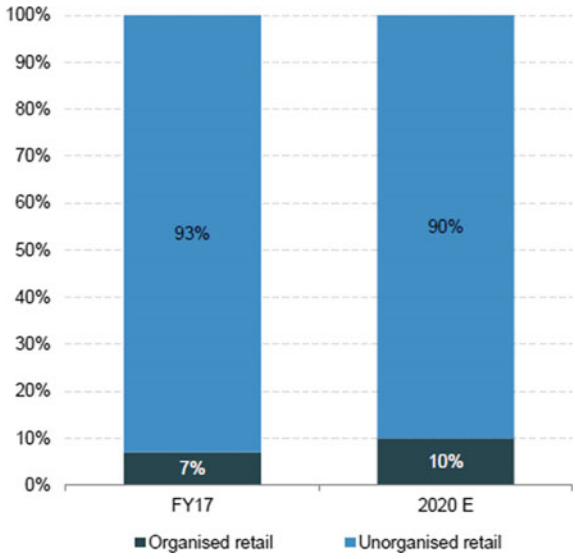

Fig. 1 Market share of unorganized and organized retails—2020 estimate [2]

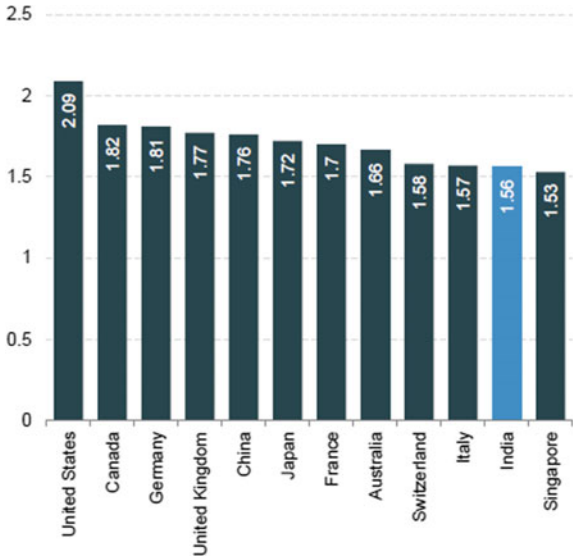

Fig. 2 Foreign Direct Investment Confidence Index 2018 [6]

similar trends [5]. With the changing foreign trade policies and liberalization, India has witnessed an honorable position in the Foreign Direct Investment Confidence Index [6]. At 11th rank (Fig. 2), India is ready to compete with the top economies in the global business environment. The more the Indian market is open for the global trends more will be the entry of organized retails and business opportunities in the

nation. It is a good indicator for the nation's economy, however, sad news for the unorganized retails.

The hefty monetary funds, state-of-the-art infrastructure, hi-tech technologies available with the global business players will hamper the growth of unorganized retail. They will pose a great challenge for them to remain competitive in the broader market. Until now, the unorganized retail leveraged upon its inherent business features viz. interpersonal relations with the customers, credit system, and close vicinity with the customers. On its own, it was a self-organized system for all the unorganized retail owners where they had their area and fixed customers. Recently, this notion has been challenged by the entry of E-tail and home delivery systems adopted by organized retails. In the last decade, E-tail entered the Indian market and started expanding its roots exponentially. As per the report of IBEF, in 2015, online retail has done business of 13 billion USD. In 2016 it grew by 11.5%, and in 2017 it grew by 22.75% and is expected to witness similar trends in coming years too (Fig. 3).

The ease of shopping and rising customers' confidence in online stores is a great threat to unorganized retails since their market share is being distributed in emerging market trends. Not only online stores, but the whole network is replacing the existing logistics system of unorganized retails. Many people have recognized the potential of E-tail and e-commerce and are switching their mode to these latest technologies. But this business model does not have enough space to accommodate the entire unorganized retail sector. The growth of the E-commerce market is also exponential. As per the IBEF forecast, the E-commerce market will show a growth of 256% in just three years and 512% in just 9 years (Fig. 4). This rapid expansion of the market

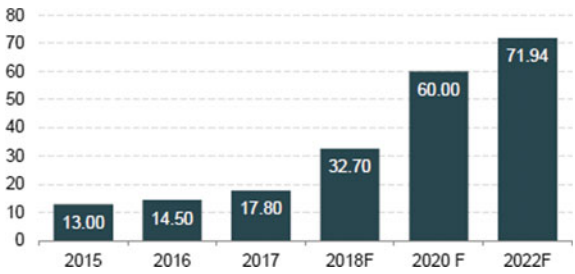

Fig. 3 Online retail share in the Indian market (US$ billion) [2]

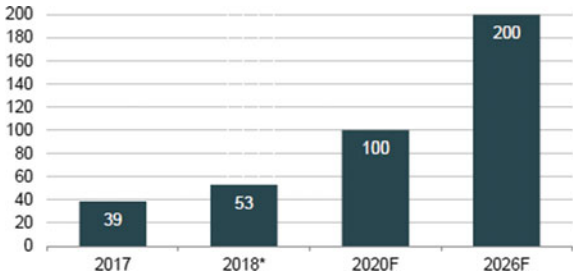

Fig. 4 Indian E-commerce Market (US$ billion) [2]

is going to have sharp cuts on the unorganized retail market due to its slow adoption of technology [2].

Here it is important to note that the unorganized retail market has another good prospect that the rate of growth of the Indian market had remained outstanding. Considering the historical data of the Indian market, it exhibited a cumulative average growth rate of 7.82% (Fig. 5). This can be attributed to the rapidly growing middle class. The average income of the middle class is increasing, resulting in the increased purchasing power. Now the people are moving from the purchase of necessities to luxury items. The easy loan and financial support from the banking and financing institution also play a significant role in increasing the purchasing power of Indian citizens. The overall living standard of the people is changing with aspirations of global standards [1, 2].

Several researchers have tried to assess the parameters that impact the customer perception and liking towards market segment for their purchasing needs. Primarily such parameters include courteous salesperson, respect for the customer, product quality, service quality, store cleanliness, reasonable price, digitized facilities for product selection, easy payment, etc. Such studies conducted within various organized and unorganized retails revealed that the small retails are aware of the competition from organized retails and are paying more attention towards these parameters, especially cleanliness, to remain competitive [7, 8]. Researchers have also hinted at the adoption of technologies to improve the customer experience. Simple and easily adaptable technology features vested within smaller gadgets/equipment can prove beneficial to business ventures. The mobile-based applications viz. scan and go technologies, self-check-out provisions, Que-vision, and smart shelf technologies have been found successful for enhanced customer experience [9].

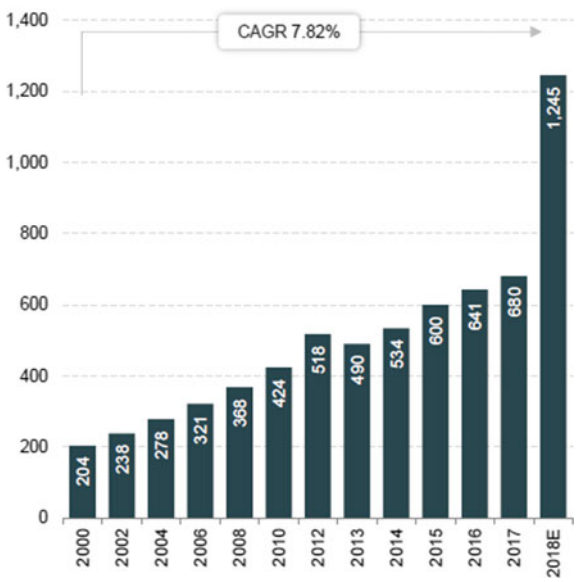

Fig. 5 Market Size (2000–2018 E) (US$ billion) [2]

Adding additional channels of doing business is also an important business strategy that can prove beneficial for the business growth of a firm [10]. Presently, the addition of channels of retails is being adopted by some of the players in unorganized retail; however, these are visible in limited segments. The unorganized retail is collaborating with the online stores to have better exposure to the customer base. Through this channel, the retailers are supplying to their own locality and selling their products all around the nation. The early adopters of multi-channel retails have exploited this opportunity. The amalgamation of all these business features (traditional and modern) within a context-specific innovative product/ intervention can equip the unorganized retailers with enhanced capability to compete and can promote their well-being and prosperity [11].

In the dynamically changing Indian market witnessing the shrinking of unorganized retail and the challenges being faced by them to compete with global organized retail, there lies a dire need to equip and strengthen the unorganized retailers, especially the street vendors. Presently, there lies a paucity of such interventions equipping marginal street vendors and provides plenty of scopes to intervene to better the existing prospects. The plenty of street vendors dwelling on meager business sale profits need to be empowered with context-specific innovative business solutions that can enhance their business prospects to increase their earning, efficiency, and ease of promoting occupational well-being. Modern-day technology-enriched low-cost solutions can be thought of in the local context for such needs. These may help the unorganized sector to remain vibrant, self-sustainable, competitive, harmonious, and prosperous in the longer run.

Realizing the miseries of marginal street vendors and their uncompetitiveness to compete with the technology-equipped organized sector, the researchers in this present research propose a context-specific technology-based innovation as a mitigating solution. The current research aims to provide a design intervention that could empower street vendors with a digital platform to enable them to sustain and compete in a modern market setup. It would help them to grab an equal opportunity and market presence compared to contemporary online market formats.

2 Methodology

Initially, the preliminary market surveys were carried out in several tier II and tier III Indian cities. These aimed to understand from the street vendors about their the inherent work parameters, business strategy requirements, commonly used tools/equipment/devices, available infrastructure (vending cart, rickshaw, rehri, etc.), available space allocations, ease to public spaces and facilities, educational level, etc. The vendors involved in unorganized retail were observed both in static market setup, e.g., local Sunday markets, weekly haats, etc., and plying on street/roads selling their products to designated localities in their vicinity. Interviews were conducted with several street vendors to understand their routine work, pain and frustration points,

likings and dislikings about present infrastructure owned, features and requirements in prospective infrastructure, financial capabilities/limitations to own specially designed infrastructure, etc. These approaches provided a lot of understanding of the need/ requirement and features they anticipated in the intended product/equipment.

Further, to narrow down the scope for practical reasons of developing the context-specific intervention, the unorganized street vendors dealing with daily-use perishable products (vegetables, fruits, dairy products, etc.) were selected as a target group. The intended innovative product/ system will cater to the specific needs of such vendors and will equip them with modern technology features to remain competitive within the prevailing dynamic market scenario. Several concept sketches and renderings of the proposed design intervention (vending cart) were developed considering the intended features/requirements. Those were further screened using several pre-determined checkpoints/constraints. The basic framework of the digital system module for automating the inventory management and billing facility was conceptualized simultaneously and was put for validation. User surveys were conducted to get feedback from the target groups to know the pros and cons of the product for further future improvisations. The Intellectual Property Rights (IPR) were obtained to retain the exclusive rights towards the further development, marketing, licensing needs.

3 Design Intervention: Features and Working Details

From the responses and understanding gained about the street vendors' needs, demographic details, etc., it was observed that they belong to the lower-income group having minimal formal education (typically primary education). The most common device/apparatus that forms an integral part of their livelihood generation is a vending cart (rickshaw/rehra). They ply on that to sell/deliver their products far and near. In addition, they generally possess a weighing machine, mobile phone, temporary lighting arrangement, a small wooden box for cash, and their products. It was proposed to enable their vending carts with multiple modern-day facilities that could ease their daily routine affairs and empower them to compete with facility-rich organized retails. The proposed intervention would also provide an additional channel/portal for enhancing their digital presence and sales perspective, without the requirement of any additional infrastructure (shop, mall, etc.). Such an intervention need to be cost-effective, user-centric, feature empowered, easy to operate and handle (minimum human interaction required), etc.

The proposed intervention included only a limited resource viz. commonly used vending cart, a smartphone, and a weighing scale to fulfill all these criteria. It aimed to digitize the street vendors' business needs (buying, sorting, selling) and integrate them with their prospective customers via a system utilizing minimal technological gadgets. The innovative intervention includes the weighing scale to record weight data of procured fruits and vegetables, a smartphone with a camera to capture images of the fruits and vegetables to upload inventory and data cables for feeding and

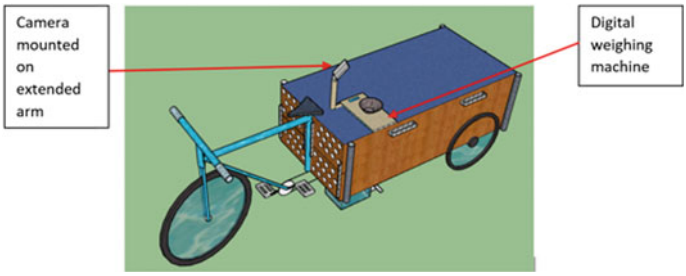

Fig. 6 Vending cart with weighing machine and smartphone camera fixed to a frame

retrieval of electronic data captured. The accessibility of mobile data for accessing the cloud storage and Global Positioning System (GPS) tracking and navigation is further solicited. Such a system integrated with vending cart will enable and automate the inventory management and billing facility automated and user-centric. It will empower both buyers and sellers with digital power and will enhance their user experience. The component and working details of such a system/intervention are explained in subsequent sub-sections.

3.1 Component and Working Details

A digital weighing machine is attached/ placed within a traditionally used tri-cycle vending cart, as depicted in Fig. 6. It is attached with a frame to mount a smartphone with a camera for capturing an image of the procured product for inventory update and management. The position of the image capturing device is such that it can clearly take a picture of the weight displayed on the digital weighing machine along with clear pictures of the products (vegetables, fruits, etc.), as demonstrated in Fig. 7.

3.2 Capturing Image and Weight Information

The position of the camera remains fixed upon the fabricated frame (upon extended arm). This frame is attached to the vending cart, and the weighing machine is placed on the frame. For image capturing purposes, while the camera is mounted and the setup is ready, calibration of the frame's position is done. Three red dots are marked on the corners of the weighing machine, and three blue dots are marked on the corners of the digital display section. While the calibration, images of products are captured.

The backend algorithm identifies the digital display section and the weighing machine area. The three dots helps in identifying the digital frames of the images to be analyzed. Critical care needs to be taken in this procedure that the basket holding

Fig. 7 Image of a product available in the vending cart and placed on the weighing machine along with a weight displayed on the weighing machine

the products must be placed within the digital frame of the picture and should not be projected outside from the weighing machine.

3.2.1 Identification of Product Type (Sorting) and Inventory Update

For accomplishing this module, various steps are involved. These are discussed in detail in the following sub-sections.

4 Data Sorting and Analysis

Initially, the segregation of weight data and images is done. These are isolated into the product frame and weight frame separately. Further, **t**he image in the product frame (basket frame) is analyzed to identify the products by comparison with the closest resembling images available in the database. The analysis of the data/identification of the product is done with the help of Convolutional Neural Networks. The picture within the frame can include a plurality of tiny pixels, wherein each pixel carries a set of RGB values. These values decide the actual color of the pixel, and all the shades of colors have a very distinct combination of the RGB values. Similarly, a set of neighboring pixels with distinct color combinations form a pattern, such as a set of patterns for a shape, texture, line, edge, etc. Thus, by identifying the set of pixels

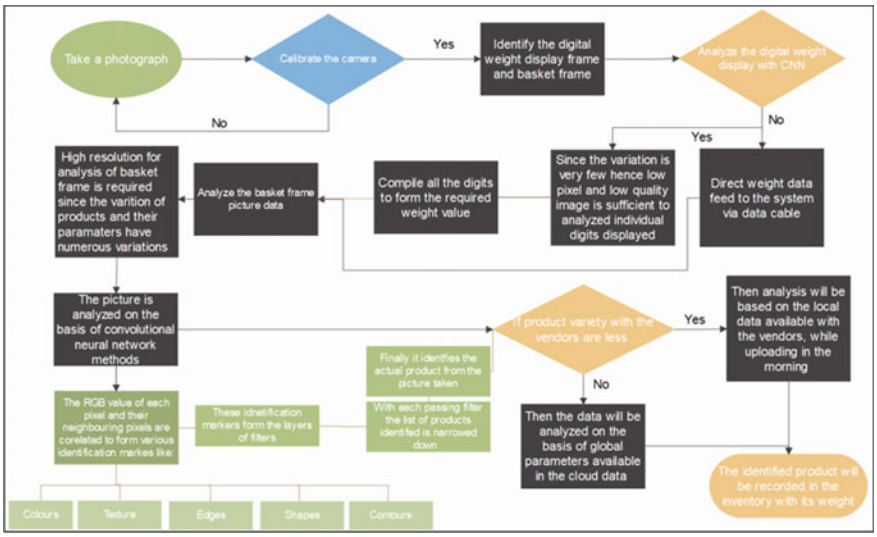

Fig. 8 Data analysis flow diagram (Identification of product type)

for their distinct RGB values, any of the physical shape or other properties can be formed in the image (Fig. 8).

Practically, it is difficult to identify a large variety of products solely based on the formation of shape/ pattern. To overcome this difficulty, distinct identifiers are linked with a distinct set of parameters and are fed into the computer systems/applications in advance. For example, in our product case (fruits, vegetables), a red-colored item, somewhat round in shape, with a depression on the top, can be identified as an Apple, Cherry, Strawberry, etc. However, if it is further filtered with yellow dots and a pointed bottom, it can be perfectly judged and identified as Strawberry only. If the filter is able to identify a depression at the top and bottom portion that consists of ridges, then it will be identified as an Apple. In the case of Cherry, it needs to be completely round from the bottom to be identified as Cherry, unless something else also has the same identifiers. The level of accuracy can increase with an increased number of filters and with increased data of exceptions added to the system. The filters can be added based on the parameters viz. color, texture, edges, contour, etc.

The products can be easily identified from the data generated during prior updating of the inventory. Thus, by mapping the pixel scores on the image, the texture, edges, shapes, contours of the product can be easily identified. Any given vegetable or fruit will have a distinct set of these parameters and hence can be easily identified when these filters are applied. Each vegetable can have a set of parameters needed to exactly identify the product, even after possessing multiple variations. It can be easily understood with the help of the identification matrix mentioned in Table 1. The nomenclature of each parameter is also mentioned below:

Nomenclature:

Colors: G—Green, Y—Yellow, R—Red, BR—Brown, etc.

Table 1 Identification matrix

S. No.	Vegetable	Colour	Texture	Edge	Shapes	Contour
1	V1	G	S	L	I	S
2	V2	R	SS	LC	C	S
3	V3	G	S	L	O	R
4	V4	Y	R	LP	C	P
5	V5	G	Sh	NL	E	R
6	V6	B	S	LC	B	D
7	V7	R	SS	LC	I	D
8	V8	G	S	NL	B	U
9	V9	Y	R	L	C	U
10	V10	B	Sh	L	C	P
11	V11	G	R	LP	O	P
12	V12	B	Sh	LP	B	D
13	V13	G	R	L	B	D
14	V14	Y	SS	NL	E	S
15	V15	B	Sh	NL	E	S

Texture: S—Smooth, SS—Semi-smooth, R—Rough, Sh—Shiny, etc.

Edges: L—Linear, LC—Linear and circular at edges, LP—Linear and pointed, etc.

Shape: C—Circular, O—Oval, I—Irregular, B—Bulged, E—Eye-shaped, etc.

Contour: S - Spherical, R - Ridge, P - Plateau, U - Uneven, D - Depression, etc.

5 Data Transfer

Data is captured in two forms, viz. picture form and digital weighing machine value input. The visual data in the form of a picture/image is transferred through the mobile network (long-range communication) or via a short-range network with the help of blue tooth or wifi. The weight data gathered from the weighing machine is transferred via data cable to the Human–computer Interface (HCI) module.

6 Data Storage

All the data is stored in the cloud, and a copy is saved in mobile for a given period. Dedicated systems viz. Database Management System (DBMS), etc., may be used to store data. All the data are converted into accounting statements for the vendors, and the customers receive the auto-generated bills on their mobile through digital

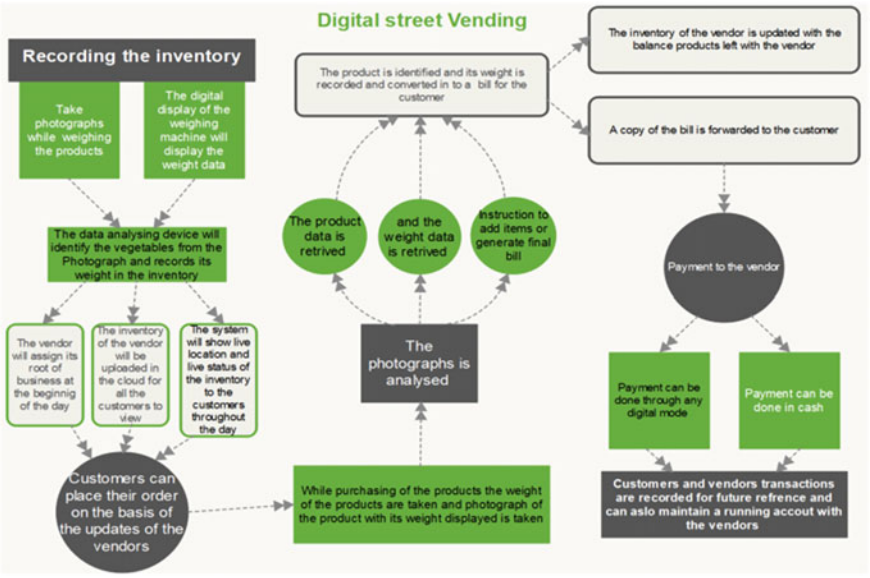

Fig. 9 The overall functioning of the developed system

message/SMS or mail. At the end of the day, the vendor can access the entire data in a simple and easy-to-understand format for their entire day's earnings.

7 Data Retrieval

All the vendor or customer data can be retrieved from the history section of the portal with a designated login ID or through a simple One Time Password (OTP) system on their mobile as per their need and requirement.

This system can digitize the vending experience and make it simple to use and operate with the help of minimal infrastructure required. The overall functioning of this system is depicted in Fig. 9 for easy understanding and familiarity with the intended system devised.

8 Discussion

This context-specific innovative system developed incorporated over a tri-cycle-based vending cart was demonstrated and explained to the 45 vendors in Guwahati and Jamshedpur through presentation cutouts. Their feedback was taken using the System Usability Scale (SUS) [12]. The SUS is used to measure the perceived

usability of the system. Researchers have extensively used it to evaluate the system's usability in mobile app development [13], healthcare devices [14], etc. The SUS score of 68 and above is considered significant. For our innovative intervention, the SUS score of 89 was obtained post feedback from the street vendors. This indicates that they felt satisfied with the intended use of the developed intervention and conveyed trust, interest, and liking towards it. It can be assessed that the product was well received by the intended users and can further be developed in full-scale at the mass production level to benefit the target group.

It is pertinent to note that the vendors found the working of the application to be very user-friendly with respect to HCI. They also responded that such a system could empower them with the digital interface without incurring any additional financial burden. They can have their presence in Omni-market formats using it. It seems very promising to them.

9 Limitations and Future Scope

The present context-specific user-centric innovation is based on pre-defined algorithms incorporated into a dedicated system that may have technical glitches in the initial stage. Such technical glitches and other shortfalls can be tackled during the beta test of the required mobile app and other digital interfaces. The initial cost of developing the mobile app and other digital interfaces may seem a costly affair at the initial stages. However, its development on a mass scale will significantly reduce the development, licensing, and distribution costs.

The researchers have been granted both Indian utility patents [15] and Indian design registrations [16] for the intended product to harness their intellectual value in the future. After commercial launch of the product, it will empower the marginal street vendors to promote their occupational well-being and prosperity. The study [17] have also emphasized that unorganized retails on high demand by the citizens of the city in spite of the increasing influence of organized retails, hence the research will strengthen the unorganized sector with digital capabilities.

10 Conclusion

Following the current research, a user-centric innovative intervention for digitizing street vending was developed to empower the marginal street vendors to enable them to compete with the technology-backed organized retail sector. The developed product is cost-effective, easy to use, and has the potential to become a marketable product. It is expected to enable the street vendors to remain competitive in the ever-changing dynamic Indian market structure.

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Thermal Performance of Green Roof and Conventional Roof in the Warm Humid Climate of India

Rebecca Mariam Varghese and S. Amalan Sigmund Kaushik

Abstract The main source of heat gain is through the roof of the building due to the prolonged hours of direct solar radiation. Many studies suggest that green roof is an effective cooling strategy. The studies conducted in Europe, U.S., China and other parts of India yield different performance results due to the diverse geographical location and climatic conditions, which are quite different from that in the warm humid zone of India, and cannot be used as an effective reference. The goal of this study is to establish the thermal comfort characteristics and efficiency of green roof in comparison to a typical concrete roof in the climate of Trivandrum, through simulation and validate it with a scaled model for the months of March, April and May. For this study two cases were considered—a room with conventional roof and green roof. The methodology involves simulation and measurements from a fabricated prototype to find the indoor ambient air temperature and indoor surface temperature of the roofs and its validation. The indoor surface temperature of green roof is on an average 19% less than that of Conventional roof at peak hours. The annual simulation data for Trivandrum, Mumbai and Trichy were crossed compared and the results showed a substantial difference throughout the year which reconfirms that, the green roof is effective in a warm humid climate in terms of indoor comfort, reduction of indoor ambient air temperature during summers and keeping consistent temperature throughout the year.

Keywords Green roof · Thermal comfort · Sustainability · Test box · Thermal performance · Passive cooling

Abbreviations

GR	Green roof
CR	Conventional roof
Cp	Specific heat (J kg^{-1} K^{-1})

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G	Solar radiation (W m^{-2})
RH	Relative humidity (%)
x_I	Numerical values
y_i	Experimental values
T	Temperature (°C)
f	Density (kg m^{-3})
U	Thermal transmittance (W m^{-2} K^{-1})
To	Average monthly out-door ambient
λ	Thermal conductivity (W m^{-1} K^{-1})
T_{amb}	Ambient temperature
B_1	Box 1 with GR
B_2	Box 2 with CR

1 Introduction

1.1 Background Study

World has been dealing with major urbanization issues, including the loss of green spaces, which has exacerbated the Urban Heat Island Effect. As a result, a number of passive technologies, such as evaporative cooling, reflective materials, shading with photovoltaic panels, insulations, and vegetation have emerged. These building envelope strategies help to improve the thermal comfort and also to reduce the building energy usage [1]. The overhead plane of the building envelope receives the solar radiation for the longest time, has the greatest diurnal temperature changes, and consequently increases the building's energy use. Study shows that green roofing is the most effective cooling method. It is documented that GR increases the insulating performance of the matching CR by adding a layer of soil, but also cools the roof by shade and the transpo-evaporation effect [2].

The origins of green roofs began with the Hanging Gardens of Babylon. In the year 500 B.C. [3]. Modern green roof technology developed in Germany in the early 1700s, when the first green roof systems with sophisticated irrigation and root incursion prevention were mass-marketed. The creation of huge green roofs in the late 1800s with lighter, less expensive systems that could be used on huge flat roofs was the second major step in history. Later, green roofs were used to green large cities to replace the lost greenery and to offset the rising land prices of establishing recreational spaces [4].

Green roofs moreover have different—environmental, economical and social benefits. These include—natural air filtration, increased thermal comfort, reduce UHI, increased longevity of roof from UV radiation fluctuations and diurnal stress, a positivity to humans and provision of urban habitat [5].

A green roof refers to any rooftop—sloped or flat that supports vegetation to provide urban greening for buildings. The green roof is a hybrid of abiotic and biotic

materials that acts as a greenhouse in a severe climate. Green roofs are classified into numerous categories—deep, modular, and brown or eco roofs.

2 Components of a Green Roof

For an extensive green roof, the following should be the characteristics [5, 6]

Vegetation- The plant should have the ability to withstand drought conditions, and in case of tropical climate— waterlogged conditions also. Survive in low-nutrient environments and require less upkeep. Regrowth that happens quickly. Roots that are short and soft.

Substrate—Less expensive to construct would be by using local waste materials

Filter fabrics—should have a high tensile strength and excellent water permeability. The pores of the fabric should be fine enough to limit the erosion of substrate layer into the drainlayer.

Drainage layer—should comprise of high-strength plastics with pockets for storing water while allowing excess water to drain.

2.1 Need for the Study

Green construction is being promoted by countries all over the world to address the issue of insufficient urban green spaces by developing additional horizontal and vertical spaces. Research has offered many computational methodologies to evaluate the thermal performance of the green roof and to predict the thermal performance of the green roof localized to the experimental location. According to Simmons et al. [7], the widespread usage of green roofs has a lot of potential in subtropical conditions with high temperatures and a lot of rain. From a study in Greece, green roofs cut cooling demand by 2–48%, with an indoor temperature reduction of up to 4 °C [8]. Another study by Hernández et al. [9] study conducted in Cuernavaca, Morelos, maximum interior surface temperature of CR was 38.9 and GR was 25.5 °C. Yet there are insufficient experimental results regarding the warm humid climate of India. Studies conducted in Europe, United States and China of their climatic conditions are very different from that in Trivandrum, and cannot be used as an effective reference. Therefore, the study aims to quantify the thermal effectiveness of green-roof specific to the climate of Trivandrum and cross compare with the simulated data of Trivandrum, Tiruchirappalli and Mumbai.

3 Literature Study

From the literature study, following are the summarized statements from which this study is built upon. First the parameters of the experimental setup are discussed followed by the simulation model details. Soil thickness of 15–20 cm is enough for an extensive green roof [10]. In both hot and humid locations, 15–20% of floor space is determined to be sufficient for the opening size of a window to cater both ventilation and day lighting [11]. For a reduced scale model—either thicknesses of the model should be maintained—or even increased. Or dissimilar material scale model should be used [12]. In thermal analysis with functional scale models for buildings is 1/5 the most frequent scale [12]. Bouteloua dactyloides satisfies the criteria for choosing a vegetation for green roof according to, Li et al. [6]. Energy Plus for 2008 has incorporated an energy balance of a vegetative rooftop as per the research & validation done by Sailor.[13], which has been further used in many studies [6, 7, 9, 10, 14, 15]. It performs adequately and is used for predicting the thermal performance of green roof system in the present study.

The input variables which are critical for the simulation are thermal conductivity of soil, thermal conductivity of the structure layer, LAI of the plant and soil reflectivity. The values of the variables are available in the literature [1, 2, 6, 7, 9, 10]. These values are validated with the present climate through simulation and measurements from the prototype.

4 Methodology

The methodology used for this study involves a detailed literature study from which similar studies around the world and their findings were cross compared, the research flow of the study is shown in Fig. 1. From the literature study the research gap was identified.

From these, the variables and constraints were determined. Thus, the parameters for the model for the experiment was finalized. Then the sensors were procured at the same time Arduino was calibrated to work as a data logger. The materials for fabrication were determined after simulation of the material property. The calibrated modal and sensors were validated before installation. Validation simulation were done for Test box material and insulation, Measurement devices and its proper functioning.

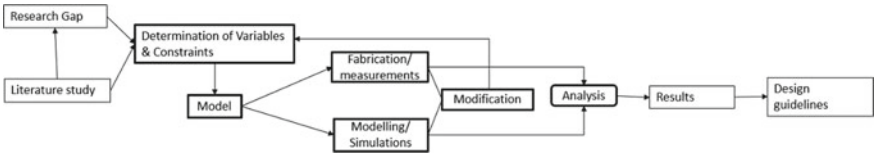

Fig. 1 Methodology flow chart

After installation of the test box and the measuring devices, data was recorded. The measurement results and simulated results, were tabulated and compared. The analysis is presented as the result of the study.

4.1 Description of Experimental Setup

The experimental setup consisted of two boxes each with an RCC roof slab. The sizes of the boxes were 0.9 m × 0.9 m × 0.6 m as seen in Fig. 2, which is 1:5 scale of an actual room of size 4.5 m × 4.5 m × 3 m. The side walls and base are of 0.02 m thick ply wood with 0.02 m thick EPS insulation sheet, as seen in Fig. 3. These walls were put together with reinforcement metal plates on the sides and L brackets at the bottom.

Fig. 2 Typical test box

Fig. 3 Box with insulation

Table 1 Measurement devices

	Test box—materials	Specs	Qty	Accuracy
1	1 wire bus temp sensor	DS18B20	6	±0.5 °C
2	Thermopile	Heat flux sensor HF POI	2	±0.1 °0C
3	Processor	Arduino MEGA	1	
4	Data storage	Micro SD Card	1	
5	Real time—readings	20 × 4 LCD display on I2C mod	1	
6	I2C temp and humidity sensor	DHT22	2	±2%

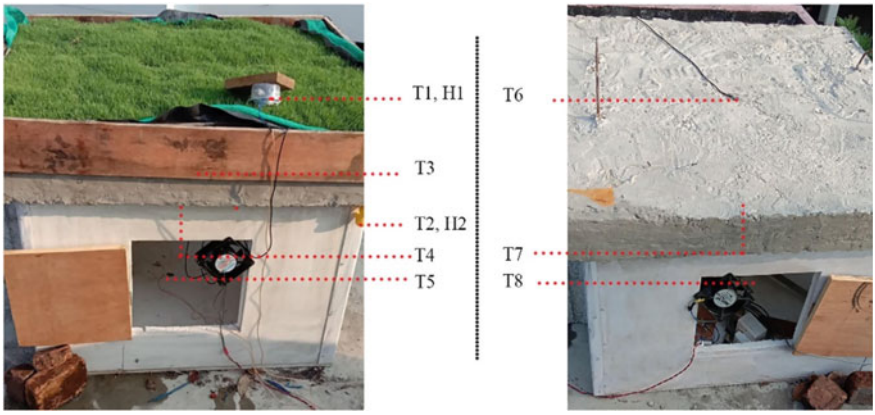

Fig. 4 Position of sensors on B1 and B2

Wooden posts of 0.07 m × 0.07 m were placed on all corners to transfer the weight of the RCC slab to the ground. Wood primer with 2 coats of enamel white paint was provided on the exterior sides of the box.

The measurement devices used were—1 wire bus temp sensor to measure the temperature, Thermopile to measure the heat flux, a Real time clock to time stamp the data and I2C temp and Humidity sensor to measure humidity and temperature. Specifications are provided in Table 1. The position of these sensors on B1–GR and B2-CR, see Fig. 4.

4.2 For Simulation

Energy Plus + open studio is used for the simulation. The energy plus comes with green roof model for simulation, incorporated by Sailor [13]. As the software performs well and is trustworthy in forecasting the thermal performance of a green roof system as seen in [6, 7, 9, 10, 14, 15], it is used in the current study also. For user interface and modelling of the room, grasshopper—honeybee plugins with rhino

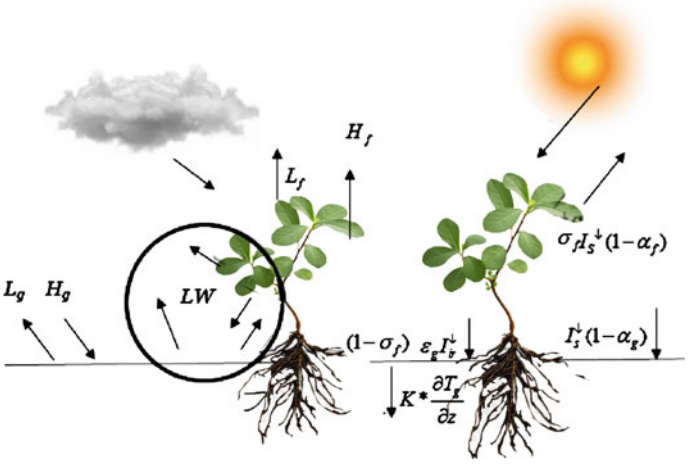

Fig. 5 Energy balance diagram for GR based on D.J. Sailors model

modelling was used. These green roof models include a vegetation canopy and soil transport model as shown in Fig. 5 that accurately simulates the following green roof physics: (1) Exchange of long-wave incoming radiation (Iir) and short-wave radiation (Is) beneath the canopy (multiple reflections, shading), (2) Canopy effect on sensible heat exchange between ambient air, leaf, and soil surfaces ie- sensible heat flux (H), (3) Evaporation from the soil surface and transpiration from the vegetation canopy with moisture inputs from precipitation (and irrigation if desired), (4) Thermal and moisture transport in the growth media with moisture inputs from precipitation. The conduction into the soil, the complicated exchange of long-wave (LW) radiation inside the canopy is also highlighted.

The equation used for the simulation, based on Sailor model [13] is as follows—the energy balance for the foliage is given by the Eq. (1) and depicts the heat transfer in the soil layer is given in Eq. (2). The details for each of the terms in these equations are not presented here, but the full model description as implemented in Energy Plus can be found in the journal article by Sailor [13].

$$F_f = \sigma_f\left[I_S(1-\alpha_f) + \varepsilon_f I_{ir} - \varepsilon_f \sigma T_f^4\right] + \frac{\sigma_f \varepsilon_g \varepsilon_{f\sigma}}{\varepsilon_1}\left(T_g^4 - T_f^4\right) + H_f + L_f \quad (1)$$

$$F_g = (1-\sigma_f)\left[I_S(1-\alpha_g) + \varepsilon_g I_{ir} - \varepsilon_g T_g^4\right] - \frac{\sigma_f \varepsilon_g \varepsilon_{f\sigma}}{\varepsilon_1}\left(T_g^4 - T_f^4\right) + H_g + L_g + K * \frac{\partial T_g}{\partial z} \quad (2)$$

The required input categories names, the final values given as inputs for the simulation and the specific value range and unit of measurement for each category is shown in Table 2.

Table 2 Inputs for simulation

S.	Variable	Values	Range/Dimension
0	Name of the plant	Baffalo grass	Bouteloua dectyloides
1	Ht of the plant	0.1	0.01 < height < 1.0 m
2	LAI	1	0.001 < LAI < 5.0
3	Leaf reflectivity	0.30	
4	Min stomatal resistivity	150	50.0–300.0 s/m
5	Soil layer roughness	Medium rough	"veryRough", "Rough", "MediumRough", "MediumSmooth", "Smooth", "VerySmooth"
6	Soil Layer thickness	0.10	m
7	Thermal Conductivity	1.35	W (m K)
8	Density of dry soil	1100	1000–1200
9	Specific heat of dry soil	1200	J/(kg K)
10	Thermal absorptance—soil	0.9	W/mK
11	Solar absorptance—soil	0.7	-fixed
12	Visible absorptance-soil	0.75	-fixed
13	Slab thickness	0.1	m

4.3 Warm Humid Cities Taken for Simulation

The criteria for choosing the cities were availability of a recent EPW file, absence of a similar study in the area and cities that have varied climate yet under the warm humid zone as per ECBC 2017 and NBC 2016. Thus, the cities chosen were Trivandrum, Mumbai and Trichy and their annual climate data are shown in Table 3.

Table 3 Climate data for the chosen cities

	Trivandrum	Mumbai	Trichy
Lat and Longitude	8.52° N, 76.93° E	19.07° N, 72.87° E	10.79° N, 78.70° E
Elevation	10 m	14 m	88 m
Annual mean temp	25	27.2	28
Yearly avg high max	31	32	38
Yearly avg low min	23	25	26
Rainfall	2197 mm	3679.8 mm	841.9 mm

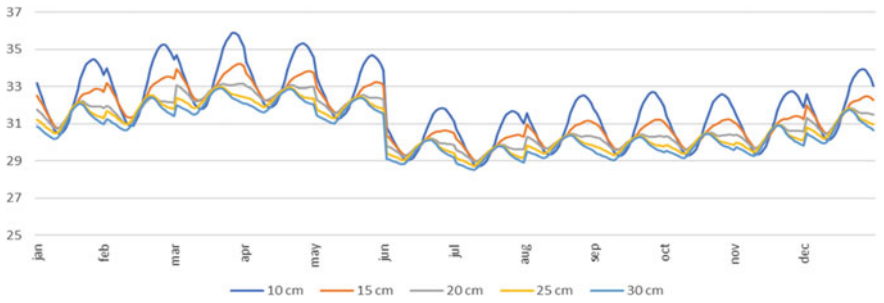

Fig. 6 Varying soil thickness simulation

5 Results

5.1 Soil Thickness

The simulation was carried out for the whole year and the results for the monthly average of each hour is plotted. From Fig. 6 it is evident that providing a 10 cm of soil thickness as input will cause great diurnal variation and providing a thickness more than 20 cm does not provide significant reduction proportional to the increase in thickness in the indoor surface temperature of the roof. Hence an apt thickness would be 15–20 cm for the city of Trivandrum.

5.2 Indoor Surface Temp—WWR 20 Open—For Different Orientation

The whole year simulation for the indoor surface temperature of the CR roof with the monthly average for each hour is plotted for Trivandrum city. Figure 7 shows that

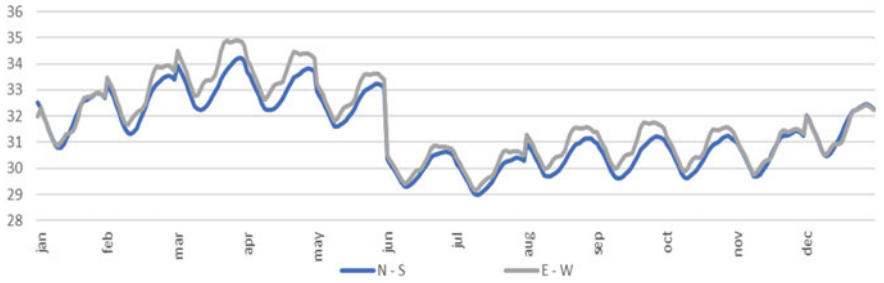

Fig. 7 Indoor surface temperature for different orientation of openings

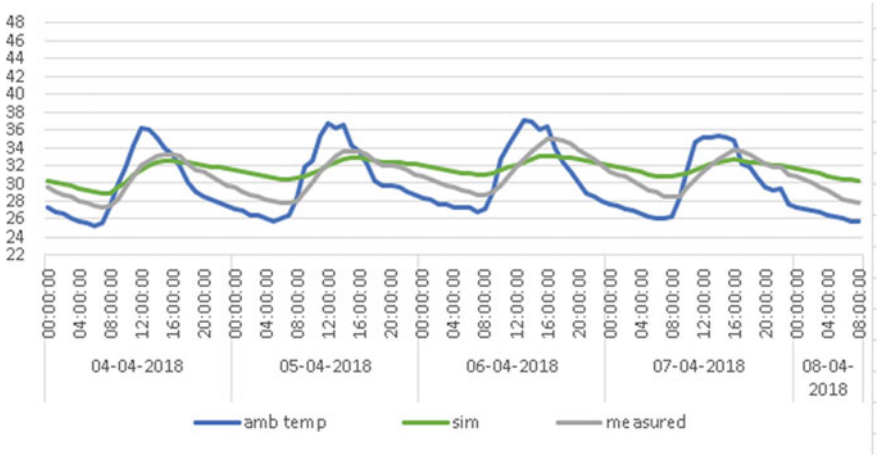

Fig. 8 Indoor surface temperature simulated and measured for GR

during the hot months a drop in indoor surface temperature by about 1 °C is seen when the opening is placed in the N–S direction than E–W direction.

5.3 Indoor Surface Temperature

From Fig. 8 Indoor Surface Temperature simulated & measured for GRthe indoor surface temperature of CR when the windows were kept open were found to be higher than the GR by an average of 9 °C (19%) at peak hours, and lower by 2 °C at night in both simulation and measurements. As seen in Fig. 8, in simulation the GR was found to have lesser diurnal variations, while the measured had more. At night the CR loses heat completely and becomes in line with the ambient air temperature in measured data as seen in Fig. 9.

5.4 Indoor Air Temperature

From Fig. 10, indoor air temperature in GR from measurement and simulation is almost coinciding and during peak hours there is a difference of 1 °C from the outside ambient temperature. Whereas in CR the measured and simulated has slight variation i.e., at night the simulated value is 1 °C higher than measured value but has a similar curve as seen in Fig. 11. In general, on comparing the two graphs, the air temperature inside the CR and GR are found to have similar curves with slight variation with the outdoor ambient air temperature, as the windows are open in the same axis as the prevailing wind direction.

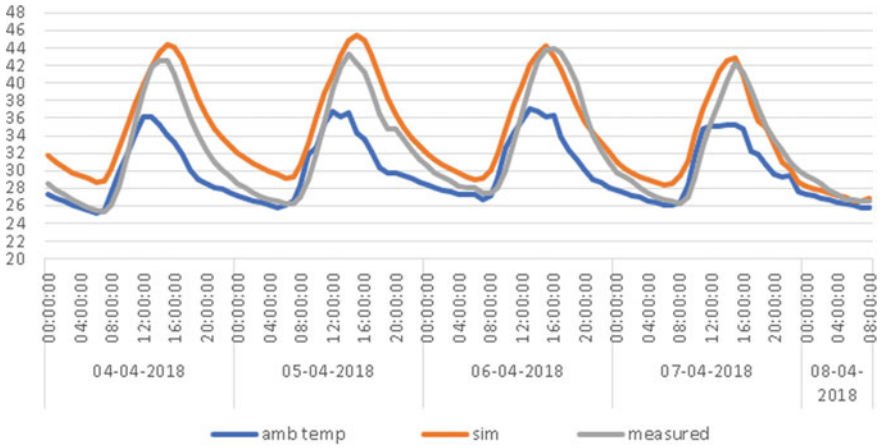

Fig. 9 Indoor surface temperature simulated and measured for CR

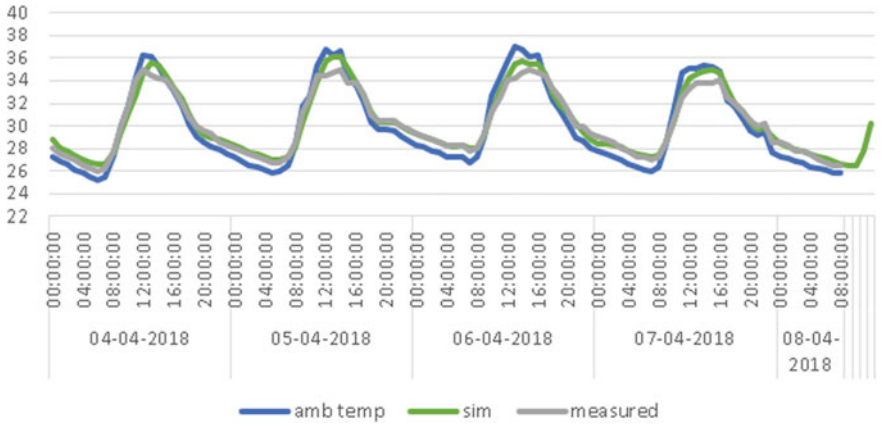

Fig. 10 Indoor air temperature simulated and measured for GR

5.5 Validation

For validation, statistical parameters are used to measure the amount of error that exists between experimental and numerical data. A quantitative comparison by root-mean-square error (RMSE) given in Eq (3)

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(x_i - y_i)^2}{n}} \tag{3}$$

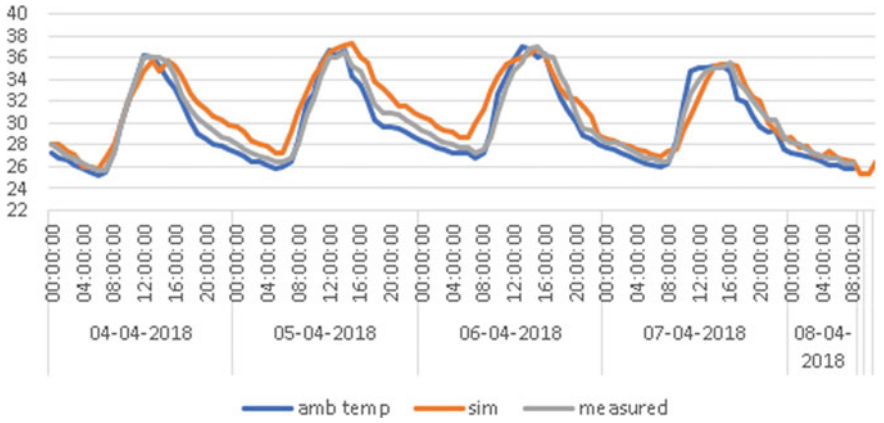

Fig. 11 Indoor air temperature simulated and measured for CR

and mean square error (MSE) given in Eq (4)

$$\text{MSE} = \sum_{i=1}^{n} \frac{(x_i - y_i)}{n} \tag{4}$$

are used, it is found that the computer simulation results for a data driven model is in par with the measured results for the same set of days (Tables 4 and 5).

Table 4 Validation for conventional roof

		Max	Min	Avg	RMSE	MBE
Indoor Surface temp	Simulated	45.40	28.39	34.92	2.86	1.93
	Measured	45.00	25.25	32.99		
Indoor air temp	Simulated	37.25	25.79	31.37	1.36	0.73
	Measured	37.00	25.75	30.65		

Table 5 Validation for green roof

		Max	Min	Avg	RMSE	MBE
Indoor surface temp	Simulated	33.13	33.13	33.13	1.40	0.70
	Measured	35.00	35.00	35.00		
Indoor air temp	Simulated	36.14	36.14	36.14	0.55	0.17
	Measured	35.00	35.00	35.00		

5.6 Comparative Study with Other Cities

On observing the annual simulated graph for Indoor Air Temperature, it is found that in Trichy and Mumbai where the diurnal ranges are high, there is a considerable difference between CR and GR. In Trivandrum the average high and average low of CR is at least 0.5 °C higher and lower than of GR. In the case of Mumbai, the average high of CR is found to be 1 °C more than GR and ambient air temp, except for the monsoon months of July, Aug and sept. From this it is apparent that the GR controls the inside air temperature within a specific range. In the case of Trichy throughout the year the average high and low of CR is greater than GR by about 1–1.5 °C, while the GR maintains the average high in line with the average high of ambient temperature and the average low about 2° more than the average low of the ambient air temperature (Fig. 12).

In the comparative simulation study on indoor surface temperature, the average high surface temperature of CR is greater than that of GR, on an average by 9 °C in Trivandrum, by 7.5 °C in Mumbai, by 10.33 °C in Trichy. This evidently shows that the vegetation acts as a barrier and reduces the heat gain through roofs. GR has a small range between the average high and average low surface temperature values in all the three cities as seen in Fig. 13. In Trichy the difference of CR, GR and ambient air temperature is relatively constant throughout the year while it varies in the monsoon season for Trivandrum and Mumbai.

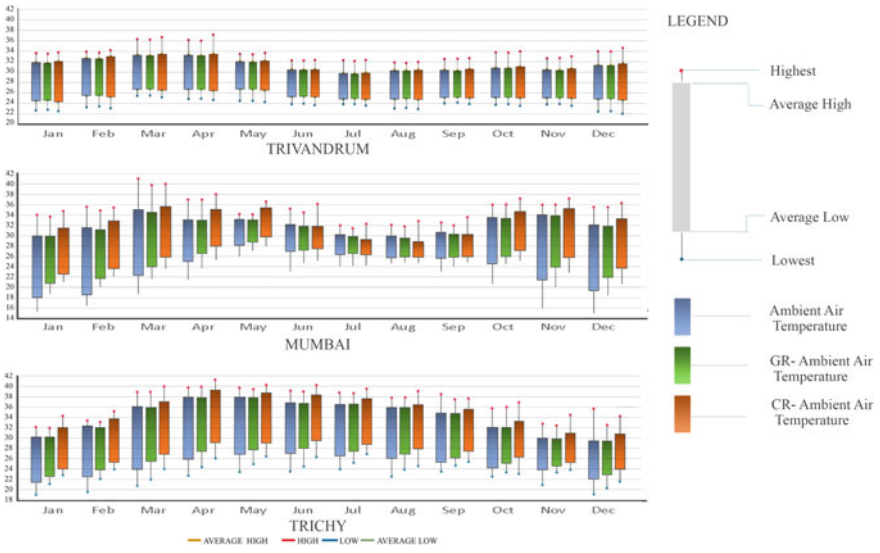

Fig. 12 Comparative study of indoor air temperature of Trivandrum, Mumbai, Trichy

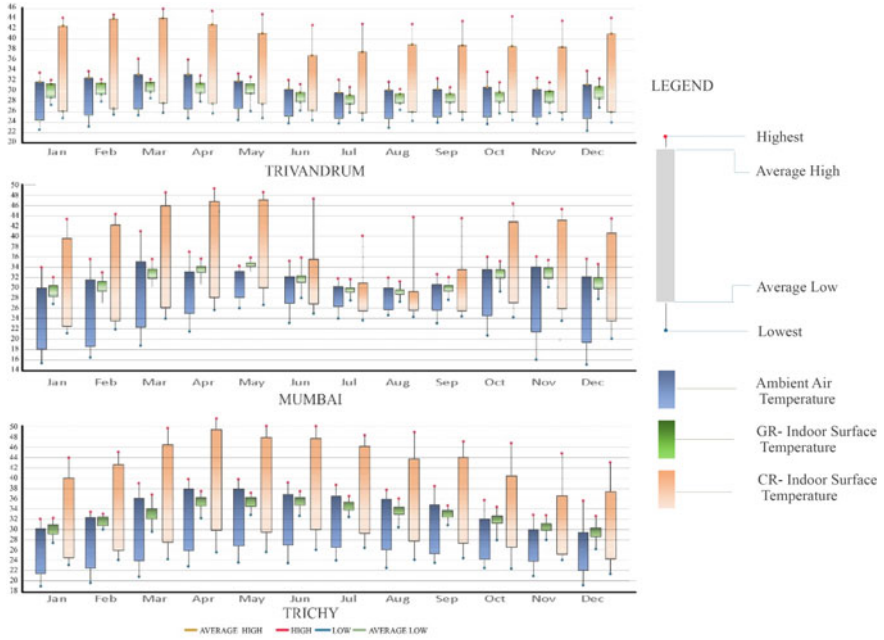

Fig. 13 Comparative study of indoor surface temperature of Trivandrum, Mumbai, Trichy

6 Conclusion

From the experimental and simulated study, it is evident that GR reduces the indoor heat gain through roof and thereby provides more comfort to the occupants below. From simulation it is seen that an apt thickness of soil for GR would be 15–20 cm and the indoor surface temperature is found to be less when the placed along the N-S direction for Trivandrum. Indoor surface temperature of GR is on an average 19% less than that of CR at peak hours. In general, the air temperature inside the CR and GR are found to have similar curves with slight variation with the outdoor ambient air temperature. The average Indoor Surface temperature simulation graphs for Trivandrum, Mumbai & Trichy showed a substantial difference throughout the year which reconfirms that GR has a good thermal performance in the warm humid climate of India.

The limitations of the present study are that the DJ Sailor Model does not consider the effect of drainage layer in the heat transfer equation of green roof. The availability of data related to LAI, stomatal resistivity and leaf reflectivity for ground covers and grass species are few. Further studies could be done on the above topics and also expand the study to other cities or by changing the parameters to provide design guidelines specific to the city.

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Re-learning Puberty: Minimising Period Shaming in Urban Schools

Kavya Kulshreshtha and Saurabh Tewari

Abstract Misconceptions, ignorance, and lack of awareness regarding menstruation lead to several issues in the urban schools in India, including period shaming. The research enquires into the understanding among the stakeholders: school-going students, parents and teachers about menstruation and its communication issues and offers designs to minimise period shaming. The study analyses the dynamics of mensuration's education, communication and real-life experiences. It employs various design research methods, including in-depth interviews with visual card sorting, semi-structured interviews and focussed group discussions. The research explores the human factors involving school-going children in dealing with culturally challenging issues around mensuration, gender roles and perceptions. It delineates the understanding for design for different stakeholders. It then proposes a multi-point design solution: including counselling sessions, curriculum changes, and an activity kit, 'Peek-a-boo', to re-learn puberty and minimise period shaming in the urban schools. It attempts to expand the emerging discussion on Social Ergonomics and Communication Design.

Keywords Social design · Period shaming · Menstruation · Social change · Menarche

1 Background

1.1 Introduction

Menstruation is a physiological phenomenon that occurs in the female body upon reaching puberty. Unfortunately, for ages, societies across the globe have developed several negative perceptions about menstruation. Women at the centre of this 'problem' face challenges in managing menstruation, physiologically and emotionally. This perceived 'problem' lies at various levels, including the infrastructure for

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menstruation, social attitude towards women, knowledge, and awareness on menstruation. Studies, including menstrual hygiene practices in young urban girls [1] and perceptions [2], presented a problematic scenario of the accuracy of knowledge on menstruation among males and females in the Indian context.

At the outset of this research, the authors assumed the inclusion and addressal of the issues by the schools at a tier-2 city in India. However, the preliminary survey unfolded another version corresponding to its awareness and policies. Despite having studied it formally in the biology curriculum, menstruation leads to a violation of human dignity. The schools' most common forms include mockery and misinformation among the other gender, including the young boys. The reluctance of parents in discussing or answering the myths and doubts on menstruation damages resolution. Further, in the school, the personal beliefs and hesitance of the educators influence the perception of a student's mind.

The shame, stigma, and misinformation surrounding menstruation, together termed as period-Shaming, remains central. To penetrate the multi-layered ecosystem of menstruation, intervening at the school level can change the next generation's mindset. The project aims to bring a behaviour and mindset change to the stakeholders (students, teachers and parents). It intends to enable them to make informed decisions regarding the issue in an urban school setting and not become a part of the problem. Though many efforts and interventions are prevalent in the field, the silence and awkwardness surrounding the topic remain a critical intervention area.

1.2 Perceptions

Two broader types of perceptions of menstruation are:

a. **Scientific**: This category covers the physiological part of menstruation, which covers everything about the menstrual cycle in a woman's body. This information remains the same across different countries, cultures and religions.
b. **Social**: This category covers the various perspectives and their nuances observed across different socio-cultural realities. Consequences of the current state of Sociology of Menstruation have direct implications on the health and lifestyle of women across the world (in different cultures and settlements).

1.3 Perspectives

Some of the perspectives of menstruation revealed varying beliefs and practices, especially in the Indian context.

a. **Religion**: Several religions contribute to shaming through their accepted literature, mentioning that a female is unclean while menstruating.

b. **Culture**: In many parts of India, the menarche is celebrated as Ritu Kala Samskara [3]. At the same time, in some families, the girl is made to sleep outside in the backyard during her 'menstruation'. The 'celebration' does not change a girl's isolation and implies that period shaming still exists.
c. **Anthropology**: Menstrual taboos [4] are at the centre of the origins of patriarchy [5], which is still prevalent in our social structures.
d. **Myths**: Myths related to menstruation restrict females from their daily activities like bathing, praying, or eating a specific food. This scenario is the same across different countries, religions, cultures. [6]

2 Research Context

2.1 Objective

The research intends to inquire about misconceptions among students about menstruation and analyse the disparity in its education and real-life experiences. Another significant aspect is to inquire about the psychological challenges young girls face at peculiar stages of menarche (onset of menstruation) and later. This research also explores the issues of under-communication, variations in gender-based exposure to the subject knowledge and its miscommunication, primarily in the school environment. It intends to find the factors that force girls to hide discussions related to the topic and address the dissemination issues.

2.2 Stakeholders

Considering that students receive knowledge from several sources during their schooling, several stakeholder groups, including the Biology Teachers (middle classes), School Counsellors, Medical staff, Menstruation workshop facilitator, Parents of concerned students, were listed. Interestingly, the students also rely on the internet to resolve their doubts or curiosity, which sometimes leads to misinformation. An iterative and non-linear project map was adopted to understand the relative perception and consequent behaviour of stakeholders surrounding period shaming in schools.

2.3 Scope and Limitations

The authors' accessibility defined the sample for interviews. Hence, insights might change with factors like the types of chosen urban context (Girls-only school, Army School, Government School). The design intervention of this project aims at

impacting human behaviour, which cannot be instantly measured. Therefore, judgement criteria for product testing were limited to two factors: acceptance of the product by the stakeholders and their feedback. The stakeholders were requested to sign a consent letter and assured confidentiality. Still, it was challenging to get people to converse. The theme of the study often became a hindrance in securing permissions from schools to interact with the primary user group, the students.

3 Research Methodology

The research examined the direct and indirect links between the stakeholders, who are either responsible or are unknowingly a part of period shaming. Careful deployment of contextual research methods like in-depth interviews and focus group discussions gauged the mindset of various stakeholders, including parents, teachers and students. A series of specially designed interactive activity-based interviews attempted to understand the primary user group, the young students. Within the course, the discussion about an emerging need to sensitise urban women about the sanitary pad disposal scenario and the ensuing environmental challenges [7] encouraged the authors to extend further the research on the plight of urban women menstruation, in general [8]. Hence, the discussions with Experts of Menstrual Hygiene Management (MHM) [6] and supporting background study were chosen for further research and decided to be period shaming faced by women residing in the Urban Setting.

3.1 Problem Context

It is essential to study the different sentiments of stakeholders towards menstruation and analyse the probable cause behind it. Scrutinising the incidents related to period shaming through several semi-structured interviews (instead, discussions) led to the observation that shaming results from a mix of fears, worries, incorrect information and myths. Proceeding structurally, the school students were the main subject of period shaming in the research. All the stakeholders, acting as multiple sources of information or knowledge related to menstruation to the students, were also a part of this research. Due to the culturally sensitive nature of the study, it was essential to understand the varying perspectives of the involved stakeholders and approach the research accordingly. Interestingly, the importance of understanding the personal inhibitions of each stakeholder group involved was realised after several failed interviews (discussed in detail later).

3.2 Research Methods

The research map and design concepts were simultaneously developed to assess the suitable positioning of the intervention. The user study involved several stakeholders like teachers, parents, school medical staff, school counsellors and students. Hence, the research planning involved different methodologies such as in-depth interviews, focus group discussions, and card sorting. The selection of the research method was made considering the required research setting depending on the stakeholder. For example, while interviewing students, setting up a comfortable, interactive, and exciting interview tone was necessary to avoid children from getting intimidated while conversing with a stranger attempting to discuss their knowledge on puberty. It was a deliberate strategy not to reveal the factor of 'shaming' while introducing the area of research to the authority as well as to the to the candidate. Instead, the research intent was portrayed as, "studying the observation pattern of students towards health and hygiene products in daily use context".

Structured In-Depth Interview and Focused Group Discussion

Stakeholder-1: Teachers (class seventh to tenth), School counsellors, Medical staff.

Aim: Assessing a classroom ambience and enquiring about the unwanted, unusual happenings while being taught menstruation. It also understands the problems faced by the teacher in educating them.

Semi-Structured Interview (Telephonic)

Stakeholder-2: Parents of class seventh to eleventh students.

Primary data collection on beliefs a today' sentences of today's world parents regarding educating their children on menstruation.

Aim: Enquiring the preferences of parents on time (age/stage of life), method, medium for educating children on menstruation.

In-depth Interview Using Card Sorting

Stakeholder-3: Students (Boys and girls from class fifth to ninth).

Aim: To analyse school students' knowledge of the practical aspects of menstruation before and after studying the Adolescence chapter [9] (Fig. 1).

Process: Two sets of cards were made. Set-1 depicted products of the health & hygiene and cosmetic industry. Set-2 depicted place (bedroom bathroom/toilet), family members (brother, sister, baby, mother, father) and time (school: daily use, for a party- occasionally). These cards were made to analyse student's uninfluenced behaviour towards sanitary napkins in all his/her natural surroundings like home, school, and market. Hence the study anchored around encouraging students to share observations of their surroundings. No direct questions on puberty or menstruation were asked to avoid any intimidation. Since tangible method was a deliberate choice and it directly influenced the research environment and human factors. The tangible

Fig. 1. Card-sorting. *Source* Author

activity, card sorting, facilitated the ice-breaking by making the participants comfortable and less awkward. Minute details of the overall interview contributed to drawing insights, e.g., a class eighth student who was not keenly answering many questions giggled the moment he turned his face away. It was anticipated that denying to recognise the image of sanitary napkins was deliberate. Studying observation towards sanitary pads was chosen to assess if the student could relate the practicality of menstruation with the theory of menstruation taught in schools or health sessions.

4 Understanding for Design

4.1 Stakeholder-1: Teachers (Class Seventh to Tenth), School Counsellors, Medical Staff

While concepts related to human biology are taught in classes, there is a sense of awkwardness and discomfort regarding communication among teachers and students. Some Biology teachers do not feel confident in educating students against myths such as the prohibition of working in the kitchen while menstruating. Some of the parents support the idea of skipping physical activities or even school during menstruation. They often rely on teachers to take care of their girl-child at menarche. They also expect schools to provide basic knowledge on menstruation to girls when they reach the end of the primary section, in this case, class five. One of the teachers mentioned the parent's, especially mothers', role in training students during the process. It seems plausible that a child cannot relate the 'theories' imparted (via science/biology books) with the daily life observations from surroundings in context to menstruation which includes the role of a sanitary napkin, blood stains and stomach-ache.

4.2 Stakeholder-2: Parents of Class Seventh to Eleventh Students

Some parents feel textbooks and schools will effectively educate them, but they fear the misguidance and miscommunication the media can provide to the children.

4.3 Stakeholder-3: Students (Boys and Girls from Class Fifth to Class Ninth)

In the process, it was observed that the class fifth students (both boys and girls) were unaware of the purpose of a sanitary napkin but had seen it at their homes, on media channels such as television or the nearby shops/markets. Some boys (class fifth) felt and related a sanitary napkin with a diaper for its packaging design. However, most of the class seventh and eighth boys were unaware of the purpose of sanitary pads. In comparison with a higher class, ninth class boys were partially aware but not confident about the purpose of sanitary pads. Interestingly, it was seen that the girls were encouraged to take an exit from the back door of the class if she stains her skirt so that it is easier to hide it from the rest of the class.

4.4 Study Insights

Shaming in schools is a combination of the attitude and perception of both teachers and students. Hence, any design intervention needs to consider both givers and receivers of education. As per the stakeholder study, the following pain points demands attention:

a. When menstruation is being taught, girls refrain from asking questions during class but ask separately after class, whereas boys have reduced queries for this specific topic. Hence, a lack of dialogue in the open escalates hesitation.
b. Children were aware of the biological definition of menstruation but unaware/partially aware of the purpose of sanitary pads.
c. Class eight textbooks may be inadequate to educate students on the practical aspects of menstruation, e.g., sanitary products, staining, and cramps issues.
d. Before studying menstruation in school, a child's perception develops around the behaviour of concerned stakeholders in his/her surroundings. By the time the child grows up, s/he witnesses the awkwardness and shaming around menstruation in the classroom, this scenario appears as a usual surrounding him/her due to past observations.

e. Due to the inhibition of parents and teachers, students do not receive an accurate response to their doubts on menstruation-related matters. E.g., ignorance/manipulation is faced when children question their parents about television/newspaper advertisements of sanitary products.
f. Probable misconception sources: Graphics on sanitary pad packaging do not contain a photograph/illustration of the user; unlike graphics of baby's diapers, even advertisements render children confused about the purpose of the pads.
g. The handling response by a teacher during a skirt staining incident makes her also a significant part of shaming.

4.5 Derivation for Design Intervention

The awkwardness and eventual assumption of information related to menstruation unintentionally lead to period shaming. Hence design intervention must aim at minimising variation in the understanding of menstruation and the attached shame.

5 Design Intervention

5.1 Various Positions

Keeping in view that multiple stakeholders are responsible for the current scenario of period shaming in schools, the design interventions use nudge theory to change human behaviour and attitude towards period shaming through various positions. Following Core Human drives were targeted to be triggered [10]:

a. Acceptance: Need for being appreciated.
b. Idealism: the need for social justice.
c. Social Contact: the need for a relationship with others.

Position 1: **Addressing shaming among teachers and students**. It targets awkwardness when the adolescence chapter is being taught in class eighth biology subject. Sometimes, teachers skip these topics, fearing the awkwardness of primary stakeholders: Class eighth students and Biology subject Teachers.

Position 2: **Addressing shaming among students**. There have been cases of mockery among students if a boy mistakenly saw a sanitary napkin in a girl's bag or a stain on her uniform. This position targets scenarios where girls are encouraged to hide their problems while managing menstruation.

Position 3: **Addressing shaming among educators (doctors/teacher) and students**. It was observed that the menstruation sessions were organised separately due to the possibility of shaming and mockery among boys and girls. The details on

menstruation given to boys and girls were also different. The girls were encouraged not to disclose the intent of the session with the boys.

Position 4: **Subtle introduction to young students (class fifth) to avoid shaming**. Because the biological age of puberty has shifted to as early as ten years, parents are reluctant to educate their children on menstruation (puberty) and instead choose to rely on school education in most cases.

5.2 Design Interventions

5.2.1 Interactive Kit for Menstruation Session, for Class Sixth to Eighth Boys

The designed kit aims at facilitating interaction among the students and health educators (organisers of menstruation sessions in schools). The kit included:

a. Sanitary napkin.
b. Disposable bag.
c. Badge with "Real Hero" written over it.
d. A leaflet with a story printed on it.
e. Package with quotes printed on it.

The design intent here was to sensitise the boys about the pragmatic aspects of menstruation by handing them over a sanitary napkin and also by sharing stories of experiences of anonymous females to make them aware of the real-life experiences of females with the hidden intent of encouraging boys to cooperate with girls instead of mocking them during menstruation. It intends that after the session, the boys can be asked to give the kit to their sisters/mother/friend as a gift which might signify their acceptance for cooperation whenever required.

5.2.2 Modification in the Textbooks for Educating Students on Menstruation

The design intent here was to provide access to information related to menstruation management in real-life scenarios. Graphics of the most common sanitary products were included in the class eighth NCERT books with the intent of proving a subtle validation to boys and girls about the sanitary product and informing them that this product has nothing worth hiding, as they observe in their homes and markets (Fig. 2).

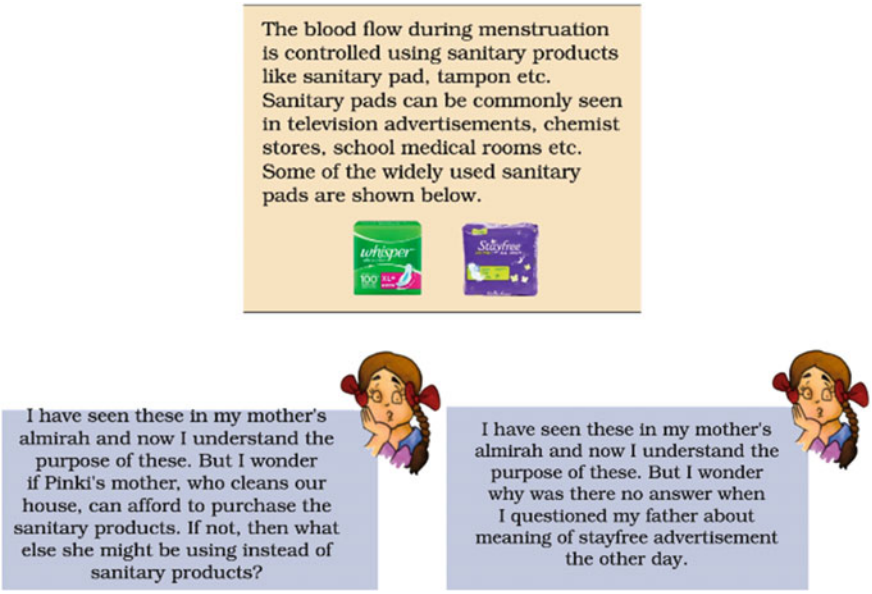

Fig. 2. Modification in the textbook (class eighth, subject: biology). *Source* Author

5.2.3 'Peek-a-Boo', an Activity Kit

The design intent here was to make students of class fifth aware of the concept of changes in the body as a part of growing up (puberty). The design intervention aimed at revamping the entire negative connotation attached to growing up/puberty. The challenge was to maintain the depth of knowledge imparted as per the target user group. A comic strip was designed to inform students about their changing bodies as they grew up through a conversation between a caterpillar and her mother butterfly. A kit named "peek-a-boo" was designed that aimed at generating excitement among students. The brand consists of a calendar (signifies the importance of maintaining a record of the menstrual cycle), daily use stationery like pencils, pocket diaries, badges, bookmarks and a pencil box like a kit package. The everyday use products were made part of the kit to encourage students to use them in their daily lives, thereby maintaining a substantial recall value of the menstruation session.

The intention was to break the stigma by putting the kit from a menstruation session to daily use. This design solution aimed to create a new normal by subtly including the peek-a-boo kit (distributed during the menstruation session) in their everyday activities. The kit contains peek-a-boo branded, commonly used stationery, which may create a recall value every time a student uses it (Fig. 3).

Fig. 3 Peek-a-boo kit. *Source* Author

6 Discussion

Along with some visible success in the process, there were some shortcomings too. In **Intervention 1**, a counsellor felt that an anonymous story of a female's experience (a part of kit designed) might not prove impactful; instead, stories about the experiences of their mothers/sisters will be relatable, hence moving. Schools usually do not allow such bold interventions (distributing sanitary napkins as a part of the kit), irrespective of the intent, since it may lead to the increased scope of mockery.

In **Intervention 2**, some parents and teachers felt that including graphics of sanitary napkins in textbooks itself would make it easier to initiate a discussion with children. Still, they also showed their concern towards the possibility of mockery in the classrooms.

In **Intervention 3**, the excitement level of the science teacher observed was high, and she felt 'peek-a-boo' has enormous potential to curb shaming. However, the usability of the elements of the kit requires rework, considering boys. The parents' excitement level was low for this design since introducing the growing up concept through this kit in class fifth felt too early.

Personal inhibitions of the parents and their children's frankness significantly impacted the feedback of designs. Consent of educators (parents/teachers/school management) posed a considerable challenge during research. Given the jam-packed schedule of schools (like curriculum and sports), it is impractical to expect a dedicated time slot for new activities intending to curb period shaming. All the interventions iterate to fit in the existing frameworks of schools. The modifications made in the textbooks facilitate easy acceptance by students since the change is minor but logical.

7 Conclusion and Way Forward

This case study and design interventions illustrate the possibilities to work in the discourse of Social Ergonomics [11, 12] as there is still a vast scope in bridging the gap between the conventional and ideal aspects of menstruation. Significantly, exploring a design that respects all stakeholders' inhibitions related to shaming can help curb it. The research components such as employing card sorting with children shows how the younger kids have unknowingly accepted the hiding of sanitary napkins as a typical scenario. Hence, the design interventions that nudge the younger kids towards new normal before reaching puberty must be explored. Shortcomings in the research were also due to the school's trust in an individual college student interacting with their school's students on such a delicate matter. Hence, organisations with trained professionals in the field of MHM can take the study forward.

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Design for Cognitive Development of Kids: A Case Study of Developing Interactive Toy for Small Children

Piyush Inchurkar and Prakash Kumar

Abstract Toys play an important role in kids cognitive and physical development. Before starting the formal education with alphabets and numbers, the kids learn and understand different phenomena around them by experiencing things through their senses. They learn about different natural objects, creatures and phenomena by touching them or perceiving them through their other senses i.e. through seeing, smelling, hearing or tasting. In this cognitive journey of learning new things, the toys play a vital role. They try to imitate the real creatures and provide the related information in an effective way much before they actually come across those entities. Designing such toys in itself is an insightful experience. The paper discusses the process of developing one such toy i.e. Crocodile toy. And details the process of how different features of the real creature have been integrated to deliver important information about it in an interactive way. The paper concludes with discussion on tentative strategies to evaluate the efficacy of the toy.

Keywords Toy · Children · Cognitive development · Design · Alligator-like toy · Ergonomics perspective · Features

1 Introduction

Toys play an important role in the cognitive, physical, and emotional development of kids [1, 2]. Cognition is the process of receiving, processing, integrating and responding to information which involves processes like attention, memory, executive function, convergent thinking and divergent thinking [3]. They engage kids and help them explore new phenomena, and build cognitive capabilities. They teach children about setting goals, helps them in resisting temptations and focus on the

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learning task at hand as well as controlling their emotions [4, 5]. They channelize their energy, improve problem-solving skills, helps in conflict resolution, and teach them how cause and effect work besides teaching about sharing and interacting with others [6]. The toys play a critical role in the early years as the learning is very fast then [7].

There are different types of toys to help kids in different ways. Some toys help in developing their fine and gross motor skills. Whereas, the others introduce them to natural phenomena and creations like flowers, fruits, vegetables, water, stones, butterflies, pets, fishes, etc. They help them using their different senses like touching, tasting, exploring colors, smelling, etc. However, for some creatures i.e. snakes, insects, alligators, wild animals, etc., direct exposure might not be feasible. But it is important to educate children about such creatures too. Different methods i.e. print and multimedia, are used to educate them about such elements, but they have their limitations [8–10]. The printed books are illustrative but not physically interactive. Whereas, the multimedia is interactive and informative with a multi-sensorial experience. However, it limits the development of a child's imagination. The longer exposure could even lead to different physical and psychological issues among children [11]. So, physical toys are the appropriate alternative to describe the concept realistically with a 3-D form. It also encourages physical interaction that helps in strengthening motor skills. However, making an appropriate toy for illustrating any living creature and all its major characteristics is very challenging. First of all, the toy should be able to demonstrate the various aspects of the concepts in a lucid way. Secondly, it should be comfortable and safe to use. Literature shows that there have been some efforts to design toys to enhance the cognitive capabilities with the safety of the kids [12–14]. However, there is still significant scope for designing the toys from an ergonomics and economic perspective by enhancing the learning experience, ensuring safety, ease of use, ease of manufacturing and repair, and reducing the cost. The paper explores the possibility of designing a toy illustrating features of a living creature with a case of an alligator-like toy design keeping the various factors in mind.

2 Method

2.1 Ergonomics Consideration

For making the new toy for the children, a holistic approach was needed to understand various requirements of the major stakeholders i.e. children, parents, manufacturers, and sellers who are directly or indirectly affected by the new solution. The majority of these requirements were addressed when dealt with through an ergonomics perspective.

The Learning Experience of the Kids. The toy should be able to enhance the learning experience of children. This might be achieved by illustrating all the features

Fig. 1 Study of different movements of an alligator (a still from A–Z-animals.com)

of the creature in an easily understandable way. In the case of an alligator-like toy, the typical characteristics related to the alligator had to be incorporated in the model. For this, different movements of an alligator were studied with respect to the movement of legs, wagging of tail, and opening and closing of jaws (Fig. 1).

The external form had to be similar to give the feel of the actual alligator. Suitable variants of primary colors had to be used to make the toy attractive and form a close resemblance with a real alligator. The interactive could be introduced in the model to make it more eye attractive and learnable for children.

Ease of Use. The toy has to be designed in such a way that it is intuitive to use. The form and weight should also be suitable for a small child to grip, hold and move, and play with it.

Safety. The toy should have a lightweight and simple form that is easy to lift and play with and does not hurt even if it falls on the children's bodies. The toy must not have any sharp edges or corners. All the screws and other materials to be concealed. Nontoxic materials and paints have to be used making and decorating it.

Reparability. Since the toy is to be used by the children, it should be made of damage-resistant material. The design of the toy must be modular that may get separated into parts due to push and pull, and easily reassembled.

2.2 Study of Existing Solutions

After putting down the important ergonomics consideration, a brief study of the existing toy was conducted to understand the basic moves and features of an alligator captured through the toys. All the options available in market were tried to analyzed with respect to their features and cost (Fig. 2).

Fig. 2 Different alternatives available in the market

The study showed that most of the toys were depicting the moves and the characteristics of the alligator partially. Some alternatives did try to capture the features but they were very expensive and sophisticated. Most of the existing alternatives are needed to be improved from the ergonomics perspective. Based on the ergonomics requirements and the existing studies, different concepts for the new toy were generated.

2.3 Concept Generation, Screening and Detailing

During this phase, different concepts were generated. These concepts were made with an aim to capture different features of the alligator. The concepts tried to capture different features (Fig. 3). These concepts were then evaluated on the basic criteria like extent to which the features were captured, ease of fabrication and the cost.

Eventually the final concept was detailed which embraced good features of different concepts. Different mechanism related to represent typical movements of an alligator was created. Initially, thermocol was used see the working different mechanism related to opening and closing of jaws, movement of legs and movement of the tail (Fig. 4).

After deciding the mechanism, the packaging of the mechanism and the overall form of the alligator was also designed using software. The possible material of the product was also finalized. It would be made using food grade plastic or wood with the nontoxic paints. The toys has wheels with attached cam mechanism. This allows the jaws to open and close and also, enables the legs in a pattern. The eccentric arrangement of wheels moved the body unevenly making the tail move (Fig. 5).

It could be held in hand or dragged and when it is dragged, the alligator opens its mouth, wags its tail and moves its leg. If the toy falls from height the wheel may come out without damage and could be push fitted easily. The part of tail has hard plastic with detachable sections push fitted from both sides. The approximate weight of the toy was 200–300 gm. The estimated cost of the toy was Rs. 200 if mass manufactured in plastic and Rs. 500 if fabricated in wood.

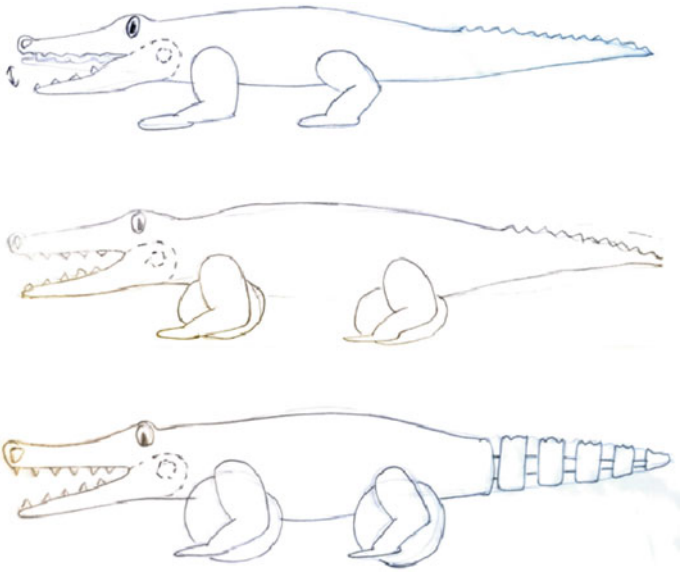


Fig. 3 Some of the concept sketches for toy alligator

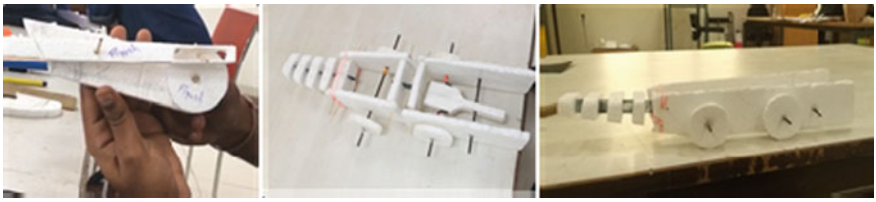
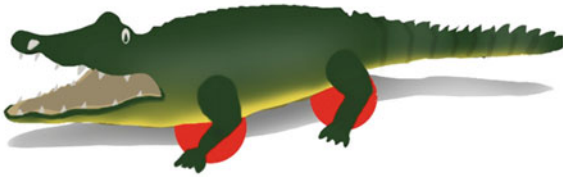


Fig. 4 Design of mechanism for actuating different movements

Fig. 5. 3-D simulation of the toy



2.4 Evaluation

This virtual model of the alligator like toy was demonstrated along with its different functions in front of a small group of parents and a few designers, separately. They were then asked to evaluate the concept and give their feedback. They were also asked to rate the efficacy of the product on the different criteria on a 1–7 rating scale.

Table 1 Rating of parents and designers on different criteria

Criteria	Parents (%)	Designers (%)
Usability	87.1	74.95
Functionality	81.8	76.1
Safety	91.4	71.4
Price	82.85	74.95

The important criteria were segregated mainly into four categories i.e. usability, functionality, safety and cost. Usability included the learning experience, interaction hap the toy, intuitiveness and the ease of understanding. During the process, 4 parents and 5 designers participated in this evaluation.

3 Result

During the evaluation, the product rated high on the various ergonomics criteria i.e. learning experience output, ease of use, functionality and safety (Table 1).

The parents liked the concept but they also if the cost of the wooden model could be further reduced. The designers also suggested certain changes in the model. They appreciated the mechanism designed for creating different movements. However, they suggested that the overall external packaging form could be further simplified. They also asked for further improvement in the modular structure of the product and suggested exploring other new materials like silicon to make the toy flexible and soft.

4 Conclusion

Though the virtual model of the alligator-like toy got a positive response from the designers and designers, the final model yet required to be improved and refined and the inputs have to incorporated in the prototyping process. It was also observed that on all the criteria, the ratings of parents were higher as compared to the ratings of the designers. This difference could be attributed to the fact that designer evaluate the product critically. Parents on the other hand sees the solution as an innovation that excites them. They also tend to ignore fine detailing. After prototyping the tangible model, it will again be taken to the parents and kids and after observations and feedback the solution would be refined to create a market ready product. Also, the various manufacturing processes will be reviewed to check the possibilities of further reducing the cost of the product. The above research also open path for studying the toys from an ergonomics perspective.

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Cognitive Ability Improvement in Indian Classical Dancing: A Study in Bengalee Females

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Abstract Lack of physical activity and increased longevity are having adverse impact on both physical and mental health in the adult population. Amongst other physical activities, Indian Classical Dancing (ICD) has its unique features including memorization. With this initial information, the present study aimed to investigate the impact of ICDs on the various cognitive abilities of healthy Bengalee adults. The study was conducted on female individuals having otherwise sedentary occupations and being trained in either Bharatnatyam dance (BD) or Kathak dance (KD) (age range 18–30 years). BD and KD had 42 and 54 females receiving training for a minimum span of 6 years and practicing either of the dances at least 360 h in a week (at least 1 h each day). The Control Group (CG) consisted 45 females of similar age, occupation, social and economic status but not undergoing any dance or exercise training. Cognitive performance analyses in terms of MMSE, SCWT, TMT, DSB and reaction time tests were done. It was found that the adult female individuals practicing BD or KD regularly have significantly ($P < 0.05$) favorable cognitive ability compared to their age, gender and occupation matched counterparts. The results suggested that BD and KD despite being a mode of relaxation helps in maintaining better cognitive ability. Thus BD and KD may be a potential tool and can be incorporated in the daily living agenda of adult females to facilitate maintain their cognitive performance and also improve the system performance as a whole.

Keywords Mental health · Reaction time · Leisure time activity · Lifestyle modification · Attention

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1 Introduction

In today's India, the fast converting urban lifestyle, which resulted in improvement in national income, per capita income, and human development Indices [1], has influenced the transport system and encouraged labor saving technologies; the latter is collectively leading to reduced energy expenditure necessary to carry out the daily chores [2]. Consequently individuals spend most of their time in either very light intensity physical activity (PA), or in sedentary behavior i.e. people are spending most of their time in activities needing 1.5 METs or less [3]. This has resulted in obvious health consequences—ranging from different non-communicable diseases like hypertension, diabetes mellitus to mental health issues [4, 5]. Along with the decline in mental well-being, in particular cognitive decline does also set in. As cognition refers to a range of mental abilities and processes that are associated with the acquisition and understanding of knowledge in respect of memory, mental work load handling, attention, judgment and decision-making [6], with deterioration in cognition, there are obvious repercussions in human performances. Cognitive decline has become one of the most prominent health threats with advancing age, and India, having a 1.2 billion strong population and rising proportion of geriatric population, is on the brink of attaining some dubious distinctions in this category. The issue has attracted widespread scientific attention due to its impact even on human performance at occupational settings and recent findings have suggested that a decline in the cognitive functions is not only a consequence of aging, but also a resultant of a decrease in physical activity since the early stage [7, 8].

Amongst other physical activities, Indian Classical Dancing (ICD) has some additional unique features that includes memorizing and facial expressions which are missing in other forms of exercises. Studies from our group for almost around a decade have clearly documented several benefits of different types like favorable body physique [9–11], cardio-respiratory fitness [12], postural stability [13] and motor ability [14] of physical activities. With such information being available in public domain from our earlier studies, the present study in particular aimed to investigate the effects of Bharatnatyam and Kathak dancing, popular ICDs of southern and northern Indian origin respectively on the different cognitive aspects of healthy Bengalee women.

2 Methodology

Necessary permission was taken from the concerned centers of repute involved in imparting training on ICDs for considerable period along with initial individual consent, and thereby the study was carried out on female individuals (age range 18–30 years) having otherwise sedentary occupations and being trained in either Bharatnatyam dancing (BD) or Kathak dancing (KD) for a minimum span of 6 years and practicing it for at least 360 h in a week (at least 1 h each day). The participants

were categorized into BD Group (BDG; n = 42) and KD Group (KDG; n = 54) respectively. Another group of 45 female individual with similar age, occupation, social and economic status but not undergoing any dance or exercise training were categorized as Control Group (CG). Those undergoing regular medical treatment, using oral contraceptives and in special physiological conditions like pregnancy and lactation (self-reported) were not included in the study. Information regarding their biological age (year), daily physical activity and dietary habits were noted in pre-designed table and their socio-economic status (SES) was found out using the latest Kuppuswamy scale [15]. Thereafter, the tests were carried out in morning hours at least after 15 min of their reporting. BMI was determined from the measured stature (cm) and body weight (kg). Cognitive function was administered with the help of Mini Mental State Examination (MMSE) [7], a 30-point questionnaire used extensively in clinical and research settings [16, 17]. Further Stroop Colour-Word Test (SCWT) [18] was carried out with the help of online stroop test where the time (90s or shorter), taken for correct response was noted. Trail Making Test (TMT) [19], consisted of two parts each having 25 circles distributed over a sheet of paper, was conducted and the time taken to complete the task recorded. The Digit Span Backwards Test (DSB) [20] included recalling and repeating the sets of no. told out in the reverse order [21]. Further, hand reaction time (RT) was assessed by a visuo-tactile task [22] given to the individuals. The average time for five trials was recorded in millisecond (ms). All the measurements were conducted by the same individual (researcher) in order to diminish the inter-observer-measurement variation coefficients [23]. Significant difference (if any) as found out using statistical tools like anova by comparing the data of BDG, KDG and CG individuals. P value lesser than 0.05 ($P < 0.05$) was considered for significance.

3 Results

Present study was carried out on Bengalee female adults residing in Kolkata metropolitan area. They were Hindu, from the middle class stratum of the society and having a sedentary mode of occupation. The individuals were comparable in respect of age, stature and daily dietary intake but differed significantly in respect of body weight; KDG and BDG individuals had significantly low BW ($P < 0.01$) in comparison to the individuals belonging to CG (Table 1).

Calculated BMI, has been presented (Fig. 1); the average BMI of BDG and KDG individuals were significantly lower ($P < 0.01$) in comparison to the CG individuals.

Cognitive ability has been assessed in terms of MMSE scores. The test includes assessing skills like orientation, attention, memory, language and visual-spatiality. Results indicated that KD Group and BD Group individuals have significantly higher ($P < 0.01$) scores, indicating a better cognitive ability, compared to CG individuals (Fig. 2).

Cognitive ability was also assessed in terms of SCWT, TMT, DSB and Reaction Time. The results indicated that BD Group and KD Group individuals have taken

Table 1 Background and basic physical information of study participants

Variables	BDG	KDG	CG
Sample size (n)	42	54	45
Age (years)[a]	20.9 ± 1.58	21.4 ± 2.12	21.2 ± 2.0
Marital status	Married	Married	Married
Socio-economic status[a]	Middle	Middle	Middle
Type of exercise	Bharatnatyam dancing	Kathak dancing	Nil
Body height[a]	154.6 ± 7.32	154.2 ± 7.17	155.1 ± 7.13
Body weight[b]	48.9 ± 5.08	48.7 ± 3.87	60.3 ± 7.25

AM ± SD; [a] ns, [b] $P < 0.01$

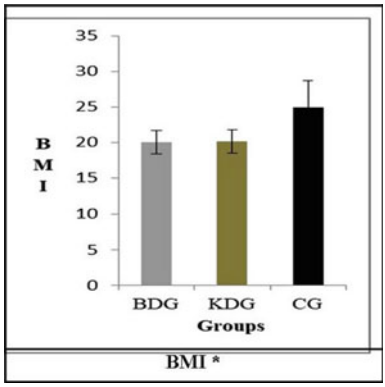
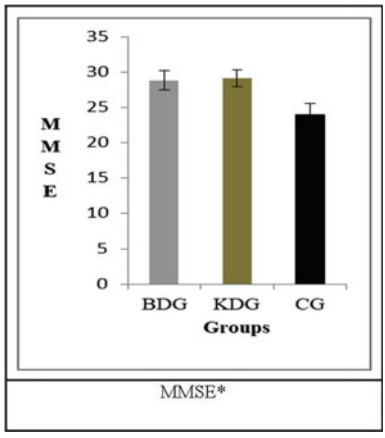
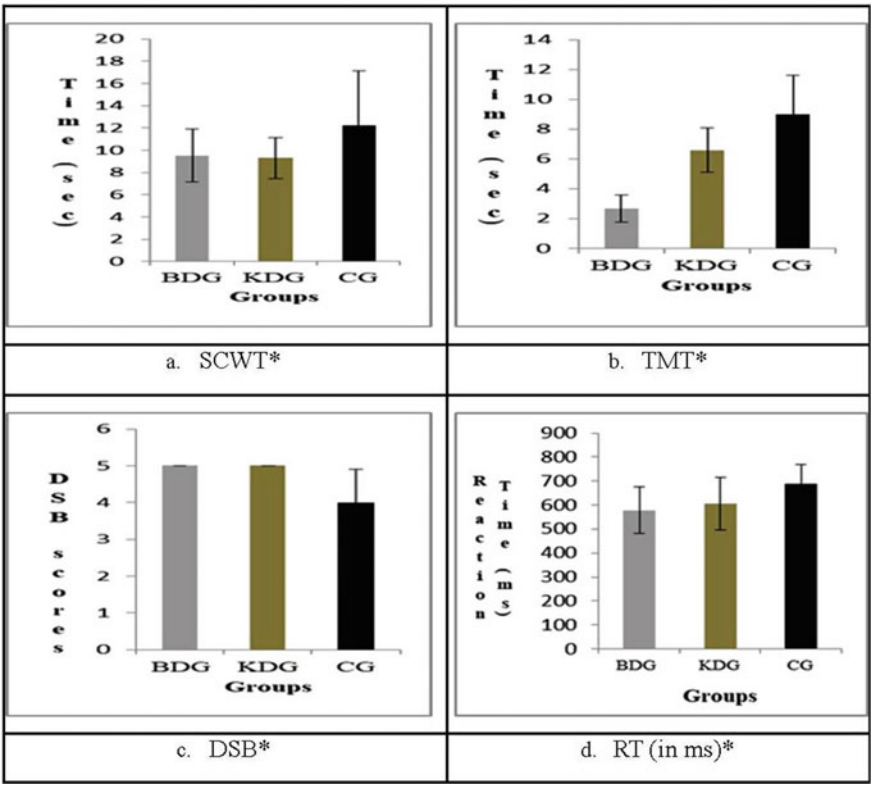


Fig. 1 Comparison between BDG, KDG and CG individuals in respect of BMI



*(P < 0.01)

Fig. 2 Comparison among BDG, KDG and CG individuals in respect of MMSE



**(P < 0.01)

Fig. 3 Comparison among BDG, KDG and CG individuals in respect of SCWT (**a**), TMT (**b**), DSB (**c**) and RT (**d**)

significantly less (P < 0.01) time to complete the task, in both SCWT and TMT tests, compared to CG individuals (Fig. 3a and b). Moreover, in case of TMT, the BDG individuals have taken yet significantly lesser (P < 0.01) time even compared to KDG individuals. In terms of DSB test, the DG individuals had significantly better (P < 0.01) score, i.e. they showed more recalling power compared to CG individuals (Fig. 3c). Further, the results of RT indicated that BD Group and KD Group individuals have taken significantly less (P < 0.01) time to complete the task, i.e. they have better visuo-tactile RT compared to CG individuals (Fig. 3d).

4 Discussion

Dancing, a group of exercise characterized by a systematic progression of motions [24], involves perception and performance to a rhythm that someone hears in the form

of music; its essence lies in the confluence of movements, rhythm, emotional and gestural representation [25]. Its extent is marked internally by the inherent condition for unconscious synchronization and externally by the body with fingers, hands and feet. Physical activity has already been accepted, by earlier reviews and systemic studies, as a strategy to address many physiological defects including overweight and obesity and its associated co-morbidities [26], cardio-respiratory difficulties [27] and lack of physical potency [28]. Moreover, previous findings have already indicated that BD and KD have beneficial effects on body physique [29–34], cardio-respiratory fitness [35–37], postural stability [13, 38] and motor ability [39]. The present study in this background was designed to assess the effect of BD and KD on the cognitive ability of adult female Bengalees. The participants, belonging to middle class strata of the society, led otherwise a sedentary life excepting the BDG and KDG individuals practiced BD and KD respectively.

BMI, a total adiposity phenotype marker, is a popular metric for assessing body adiposity [40], and helps to categorize the individuals into different groups of body fatness [41]. The results indicated that the average BMI of BDG and KDG individuals were significantly low ($P < 0.01$) and falling in normal weight category, in comparison to CG individuals—who are falling under overweight category—as per the WHO recommendation for Asian Indians [42, 43] (Fig. 1), indicating a lower magnitude of adiposity among the BDG and KDG individuals and a lesser risk of cardiovascular mortality and morbidity. The trends of these results are in tune with other studies conducted to observe the effect of aerobics and brisk walking [44]. The results are also in consonance with our earlier studies carried out on adult females practicing ICDs [39].

Cognition includes the activities concerned with the psychological processes involved in acquisition and understanding of knowledge, formation of belief and attitude, decision making, and problem solving. The results of MMSE carried out to assess cognition status indicated a significantly better ($P < 0.01$) score among danseuses in comparison to their CG counterparts (Fig. 2); indicating a better working memory among the danseuses as MMSE is an indirect indicator of working memory [45]. These aspects of dance required the procedural memory, attention, orientation and emotional expression which are actually the different components that are assessed in MMSE [20] and hence the danseuses obtain a better score. Similar results have been observed with International ballroom dance among adult females [46], Tai Chi Dance and Bharatnayam dance [47]. This may be due to the fact that BD and KD involve memorizing and retrieval of steps, facial expressions, finger gestures and apply them for a consorted performance.

A neuro-psychological test, SCWT, used extensively to assess the capability to inhibit cognitive interference, was carried out. The test involves the process by which a specific stimulus can impede the concurrent processing of a second stimulus attribute [48]. The attention control i.e. to keep undivided, focused attention at a particular task, was assessed in respect of SCWT. The SCWT values were found to be significantly lower ($P < 0.01$) among the BD and KD individuals (Fig. 3a); indicating a better ability to suppress any pre-potent response [49] among the danseuses. Similar improvement in attention control has been found with improved physical

fitness achieved from aerobic dancing, Latin dance and Cha Cha dance [50]. The favorable results of the danseuses in the SCWT indicated the impact of these dancing on the cognitive functioning, particularly attention control, probably by increasing the levels of neurotransmitters that improve neuronal plasticity. It might be due to the fact that these ICDs require both the variables—i.e. speed and accuracy—in their performance that elicits the attention abilities. The findings indicate that KD and BD may be a potent form of neuro-rehabilitation, combining highly task-specific motor and attention solicitations [51].

TMT, a short and convenient estimate of cognitive functions, principally attention and working memory, has been extensively used in neuropsychological assessment [19]. It provides information on visual search, scanning, speed of processing, mental flexibility, and executive functions [52]. Significantly better ($P < 0.01$) results have been observed with the danseuses (Fig. 3b) in TMT. The results corroborate with studies carried out on aerobic dance Latin dance, and Tango dance [51]. The better status in danseuses may have resulted as they practice movements that are organized into spatial patterns and synchronized to music; these in turn possibly influence their generalized cognitive ability in terms of speed and fluidity. It is also referred as fluid intelligence and higher cortical functions, as processing speed and task shifting are the two aspects involved in TMT. Further the BDG individuals have taken yet significantly less ($P < 0.01$) time compared even to KDG individuals, maybe due to the fact that BD requires finer tuning and precision of body and finger movements. It is a possibility that the dances facilitate individuals in better learning of a given knowledge and novel and abstract problem solving.

DSB is yet another cognitive assessment procedure in particular the assessment of working memory that involves simultaneous storage and processing of a task. The task included recalling and repeating the sets of number told out in a reverse order [21]. The BD and KD group participants have significantly better ($P < 0.01$) score (Fig. 3c); indicating the KDG and BDG individuals to have better recalling power compared to CG individuals. The results are in tune with studies conducted on Tai Chi dance [50]. As the test involves two factors of working memory structure: (i) content and (ii) function, involving coordination and simultaneous storage and processing, therefore the results indicated that KD and BD comprises of both the facets—content in the form of verbal-numerical material and function in the form of spatial material. Probably the practice of the memorization technique that is applied by the danseuses to recall the phrase or the movement might have influenced the process. Furthermore, it has been established that lyrics along with rhythmic sound, are stored in the memory easily; by the method called ostinato [53]. This probably makes the moves unforgettable and is often incorporated in the music that beats timely with the usage of hands or legs in these forms of dancing.

The visuo-tactile RT indicates visuospatial intelligence and tactile acuity [54]. Significantly lower ($P < 0.05$) visuo tactile RT, depicted by a better score (Fig. 3d), of the KDG and BDG compared to their non-dancing counterparts. Similar results have been found with female athletes [55] and Bharatnatyam danseuses [47]. The results indicated better cognitive ability and tactile acuity i.e. faster response, of the BDG and KDG individuals which might help them for better problem solving

and prevent them from falling down frequently at their advanced age. According to suggested theories, there exists a correlation between mind health and exercise, and dance is the artistic expression of mind in bodily movement. Thus KD and BD that might originate from a discrete body-kinesthetic intelligence, is a form of human intellectual activity, as reaction time as a primary measure of intelligence. This might be due to the complexity of coordination learning, concentration and quick movements that is a requisite in these dancing. KD and BD involve various postures, complex mudras and a wide-range of expressions which are consorted for a performance. The danseuses have to be very attentive which might improve their mental skills and make them more mentally alert. Hence practicing KD and BD for a minimum period of time maybe beneficial for eye-hand RT and visuo-spatial intelligence and thus enhance cognitive function.

Therefore a physically active way of life may have the possibility to prevent cognitive decline and furthermore, intervention and prevention strategies have shown the effectiveness of lifestyle modification with emphasis on regular physical activity. But in order to have effective interventions, for public health management and to re-introduce/re-initiate an active life style, among the adult population, studies round the world are trying to adopt a method, in the form of physical activity or any form of aerobic exercise, that is feasible, low cost, easy to maintain and has a novel approach [8]. It might be a traditional activity for the different ethnic populations that is deep rooted in their culture. In this aspect ICDs like BD and KD stand out to be a fairer choice as it is a recreational mode of activity having sensori-motor rhythm, and an additional physical, emotional and social dimension.

5 Conclusion

It could therefore be inferred from the results presented and discussed herein above, keeping in tune with other observations carried out globally, practicing BD and KD regularly for an hour for at least 6 years may have a positive impact on cognition, especially in terms of attention, processing speed, executive function, and working memory adjudged in terms of MMSE, SWCT, TMT, DSB, reaction time respectively on the KDG and BDG individuals in comparison to the CG counterparts. As in the present scenario with life expectancy increasing, there arises all the more necessity to a better understanding of interventions that may delay the onset or progression of age-related diseases affecting motor and cognitive ability [56], it may be beneficial in developing programs promoting these ICDs as a form of physical activity among adults to elevate activity level, exercising ability. This simultaneously proves to be beneficial in enhancing performance level in adults and decreases chances of or at least delays the onset of cognitive impairment in advancing years. The observations from the present study indicated that BD and KD, although being spare time activity, helps in maintaining better cognitive ability. Thus BD and KD may be a potential tool and can be incorporated in the daily living agenda of adult females to maintain the cognitive performance, and also in improve the system performance as a whole.

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Application of Immersive Media to Develop Model Making Skills of Industrial Design Learners

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Abstract Unprecedented challenges during the COVID-19 pandemic led to the educational institutes close with uncertainty around the world. To continue the academic year most educational institutions have shifted to online educational platforms. Design institutes in India too adopted online classes using various online network platforms. Immersive media, such as Virtual Reality and Augmented Reality (VR and AR) has recently gained prominence in design education. Many researchers have highlighted that the VR/AR could help students improve their performance and conceptual understanding of a specific set of learning objectives. This study has helped them to identify the most common difficulty faced during online courses like model making course. VR and AR based instruction setup that allows the collaborative discussions between faculty and students are remotely discussed. The brainstorming process was used to generate ideas for improving the learning experience in the dexterity skill-based model making course through the use of immersive media. Heuristics analysis was also conducted to ensure the usability of the AR and VR based instructional interfaces. It was observed that the interactive AR based immersive instructions are better than the VR based instructions. This study can be continued further with design students to determine how effective it is to use visual clues in a model-making course using Immersive media.

Keywords AR · Immersive media · Immersive technology · Industrial design · Instructional strategy · VR

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1 Pandemic and Design Education

1.1 Background

During the COVID-19 pandemic in 2020–2021, everyone faced uncertain confrontations [1]. Due to the pandemic, educational institutions throughout the world have been closed and academic calendars are in flux. To maintain the academic activity, most educational institutions have moved to online educational platforms. Online classes have also been adopted by design institutes in India. However, Design education deals primarily with a hands-on learning approach which requires access to workshops, tools and, in many cases, continuous one-to-one communication between faculty and student. These requirements were clamped down due to the pandemic lockdown. In Industrial design, apart from the design process, students also developed their physical dexterity design skills. People realised that online mode is the only way to conduct courses with students.

In the model making course, students must understand the concepts of form, shape and space to construct a model, as well as learn how to use tools to do so. While making the model by the learners, the tactile aspects, feel of texture, material and understanding of dimensions are very vital. They involve multi-sensorial aspects to learn as well as develop fine dexterity skills. Model making course, which requires dexterity skill acquisition, is extremely difficult to teach and learn in an online environment.

Researchers in the field of education technology are always looking for better media-based teaching solution. One of them seems to be Immersive Media. Virtual Reality (VR) and Augmented Reality (AR) can help improve student performance and conceptual understanding of specific objectives in the course. Immersive media (VR and AR) may be a very effective solution for providing interactions to design students in a model making course.

2 Design Education in India

Design education has undergone many changes and progress in India. Acceptance of design practice in India has increased dramatically. Design education has recently gained prominence with the expansion of the design industry. In India, the design education sector is expected to thrive shortly in the context of favorable demographics, increasing awareness about the importance of education, and the willingness to experiment.

Design education has been formally established in India since 1961, with the establishment of the National Institute of Design based on the Ray and Charles Eames India Design report [2]. Although it can be traced back to Rabindranath Tagore's thinking and actions, the attitude and process reflected India's struggle for independence. Neither used the word "designer," but Shantiniketan's rural reconstruction

effort is one of history's greatest design stories [3]. Through organic changes in policies and markets, design education has become an aspirational magnet for young talents over time. Design education provides hands-on project-based learning that is based on direct connections and interactions with the world.

The curriculum in Design Pedagogy is very hands-on. A design learner must understand design processes, methods and mediums. The process is the same at all levels, though the methods may differ slightly and the medium varies dramatically.

3 Learning Methods in Education

Human beings generally depend on their senses to process their information to learn. Visual, auditory and kinetic are three basic forms of the use of senses. Most students have a greater chance of using one sense than others. Two main types of theory used in educational design are descriptive theories of learning and prescriptive teaching. Prescriptive theories [4] provide for methods of learning, while descriptive theories describe the way learning takes place.

As explained by Ertmer and Newby [5], learning theory is divided into three major categories: behaviorism, cognitivism and constructivism. Experiential learning, as a subset of constructivism, is important in prescribing learning outcomes. According to Kolb et al. [6], experiential learning (Fig. 1) is based on learner constructing knowledge by interpreting their learning experience. Students learn things frequently as a result of schema formation. A schema is a cognitive construct that organizes information elements based on how they will be dealt with. Design education is very hands-on and experiential in nature; hence Kolbe's theory of the learning cycle can be used in design education.

4 Immersive Media in Education

Immersive media has recently received much attention in design education. Immersive media is defined by immersive technologies that attempt to create, or imitate the physical world through digital simulation. It is the coming together of technology and reality. Examples of immersive media include: Virtual reality (VR), Augmented reality (AR) and Mixed reality (MR). Virtual reality (VR) can be described as a collection of hardware and software systems aimed at creating a sensory all-encompassing illusion of being present in different environments [7]. The core characteristics of VR technologies are immersion, presence, and interactivity [8]. Augmented Reality (AR) is a real-world experience in which information generated from computers, sensory modes, and the visual, auditory and haptic enhance the subjects in the physical world.

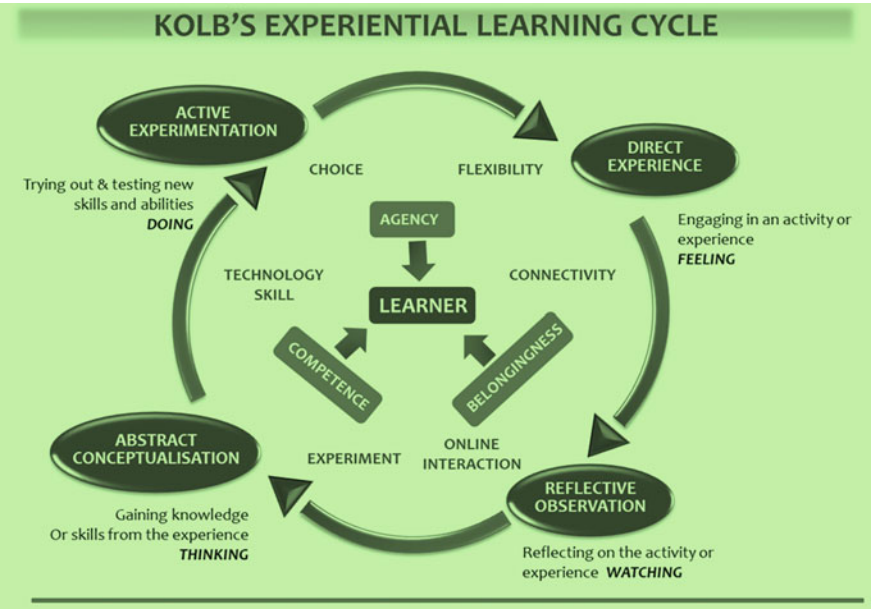


Fig. 1 Theoretical framework integrating Kolb's learning cycle and adapted from Carver et al.'s (2007)

5 Aim of the Paper

This paper attempts to develop a strategic instruction-based concepts using Immersive technology for conducting practical courses like model making for online Industrial Design education.

6 Methodology

The brainstorming process has been followed to ideate on how to enhance learning experience in model making course using immersive media. A Group of two male designers having more than ten years of design experience came up with mind mapping. A noble diagram has been created on the various parameters and their effective interactivities in the virtual media. Strategies of the basic concepts have been developed based on mind mapping preceded by the features of VR and AR. The various steps involved in model creation are properly understood from the Industrial design faculty members of X Institute of Design. Keeping learning theories in mind, instructional strategies have been developed. Various VR and AR concepts with varying functionalities have been conceptualised in detail. Furthermore, the heuristic evaluation was carried out by 5 design experts (3 males and 2 females in

Table 1 List of heuristics (adopted from Sutcliffe and Gault [9]) for expert evaluation

No.	Heuristics	Definition
1	Uniqueness of the concept	Features which is very exclusive in nature. VR and AR experiences should use visualizations and metaphors that have meaning within the physical and task environment in which they are presented
2	Functionality	Give new learning experience of using Immersive media in the context of model making course. Form communicates function. The form of a virtual element should rely on existing metaphors that the user will know in order to communicate affordances and capabilities
3	Aesthetic of the interface	Synergy in the visual look. There should have consistency of the virtual/augmented experience by respecting platform conventions from physical experiences
4	Visual feedback	Easy to navigate through, designs should work to minimize accidental distraction due to designs that are overly cluttered, busy, and/or movement filled
5	Learnability	Easy to complete the task with accuracy. Fit with user's perceptual abilities

the age group of 35–50 years) with the average of 10 years of design experience. Individual concepts have been compared and discussed in the study.

The immersive media interfaces can offer a great deal of complexity, which makes it even more important to prioritise the essentials. The fully immersive, three-dimensional nature of virtual reality allows users to see 360° and completely physical mobility, depending on the experience. Heuristic Evaluation has been done on the following points (Table 1):

7 Results and Discussions

7.1 Strategies for AR and VR Based Instructions

Interaction in a three-dimensional environment necessitates a specific training design that makes use of technology to positively contribute to learning. Chen and Teh's [10] study highlighted the constructivist aspect of learning activities in the use of VR and AR.

The Dick and Carey models [11] include identifying educational goals, training analysis, input and learning characteristics, performance targets, criteria-referenced testing, strategy and training/summative assessment. Despite the different models for Instructional Design currently in use, Branch and Kopcha [12] assume that all models include five major activities: analyzing, designing, developing, implementing and evaluating.

Shuell and Skinner [13, 14] emphasised on how fundamental learning theories can be applied in the application of immersive technology in the area of design learning, where students are rewarded or penalized for correct or incorrect answers, and thus learn about the consequences of certain behavioural patterns. This is true for applications that include a system that allows students to learn, such as responses that have (rewarding) consequences and/or responses that have annoying (punishing) consequences.

The students learn when certain results are produced and can adapt to themselves. Because immersive media is based on the experiential, an incorporative strategy for using Immersive technology would be consistent with Kolb's [15] experiential learning cycle. These learning theories operate subconsciously in the brain of the students.

The typical online teaching material consists of teaching notes, figures, written process steps, and possibly photographs displayed online on the screen. Students have less control over viewing angles due to the limitations of traditional 2D teaching notes. Student learning capabilities could be based on evaluation components such as model visualization, geometric analysis and accuracy and proficiency in understanding dimensions. The idea about proportions and scale can be visualised through Immersive media. The instructions based on AR/VR can provide enough Visual Clues to the student for the ability to learn and correct themselves.

7.2 Strategy Concepts for VR

Students in the model making course begin by sketching out their concept and finalising the form for making the model. After that, the sketch should be translated to a CAD/Autodesk model and digitally rendered. Finally, the model is translated into a physical model using materials such as MDF (Medium Density Fiberboard), thermocol, POP (plaster of Paris), and so on. The faculty usually gives verbal instructions to the students. The students understand the process and work closely with the faculty. With practical feedback the final model is assessed in person. Evaluating the model making course online is a significant challenge. The use of VR and AR would aid students in providing feedback and completing assessments in a more efficient manner. The VR setup would remotely connect students and faculty, allowing them to collaborate on feedback sessions.

Dimensions are critical when creating a CAD/Autodesk model and students can use a VR setup to compare the sketch drawing to the virtual model. The virtual model can be rotated and viewed from any perspective. Using overlay mode makes it easier to understand any volumetric differences in the virtual model. The student will be able to do the analysis better and do the corrections before translating it into physical model form with the understanding of proper proportions and 1:1 scale (Fig. 2). The student will be able to show the virtual model from all angles with complete rotation in the VR learning environment. The nodes of the model can give extra information by just tapping them. Ray-casting can be used in popping the panels. Textures on the

(a)

(b)

(c)

Fig. 2 VR based—instructions concept. **a** Comparison of the sketches with the virtual model. **b** Interactions will be aided by VR features such as the overlay method and rotation, different textures could be tried on. **c** Scaling of the virtual model to feel the actual size

model also can be changed and tried out. A clear sense of the scale to the proportions could be done in the virtual environment. At times, students may struggle to grasp the concept of the 1:1 scale. The virtual reality setup will allow students to get an actual feel of the finished model virtually.

7.3 Strategy Concepts for AR

AR could be explored to assess the later stages of model creation, where students need to translate from the CAD model to the actual physical model. Students could use augmented reality (AR) to compare the physical model to their virtual CAD/Autodesk model on their mobile or tablet device. The edges of the physically created model can be detected and matched to the virtual model using Object Recognition with AR. Matching models through AR provides a 3D color-coding overlay for required correction with 'red' and 'green' for the correct correspondence. The immediate visual feedback makes the interactivity better. It offers suggestions as to how the model can be improved and corrected.

The overlay method could be used to detect differences between a virtual model and a physical model. It will make further suggestions on how to do the required correction. Object recognition assessment opens up a plethora of possibilities and simplifies the learning process. In Fig. 3, AR will enable the model to be reviewed in a real-world environment. This allows the student to clearly understand the proportion of the model and also study the efficacy of human factors in the intended environment. This process will help to judge contextually how the model and its elements feature look at the actual scale.

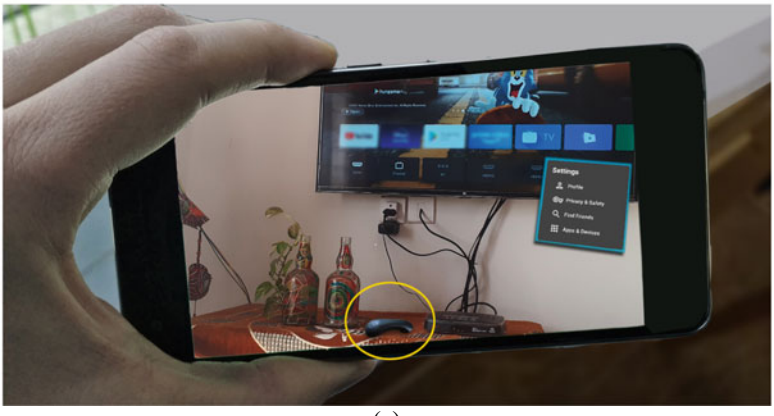
7.4 Heuristics for the Developing Instructional Strategies for AR/VR

The instructional immersive media-based heuristics improve students' learning experiences. Furthermore, when compared to a static interface, the results of AR/VR concepts show that student involvement is higher and more beneficial to both faculties and students. Immersive media allows one to reintroduce into the online environments some of the most powerful pedagogical tools which need to be tried over to traditional educational space. The immersive media makes it connect remotely and allows doing the interactions synchronously or asynchronously.

Immersive learning gives students control over their learning outcomes by connecting them to real-life experiences. Immersive media allows for the analysis and encouragement of self-learning not only in the education arena but also in a variety of other applications such as raising social awareness. A sensitive subject

(a)

(b)



(c)

Fig. 3 AR based—instructions concept. **a** The edges of the physically created model can be detected and matched to the virtual model in the AR setup. **b** An overlaid model would give volumetric comparison. **c** It also enables to simulation of the model to be reviewed in a real-world scenario

Table 2 Comparative heuristic study of VR and AR strategy based concept interactions

Criteria	VR based instruction concept	Remarks	AR based instruction concept	Remarks
Uniqueness of the concept	2.80	Context is new	4.20	Effective way to communicate
Functionality	3.00	Remote learning	4.40	Beyond geographical boundaries
Aesthetics of interface	2.60	Navigation interfaces	3.30	Synergy
Visual feedback	3.80	Able to view in 1:1 scale	4.60	Scaling and viewing in real life context
Learnability	3.40	Comparable understanding	4.40	Faster understanding
Total average	3.12		4.18	

such as menstruation could be dealt with maturely through immersive media, [16] providing visual clues to self-learning to adolescent girls from rural backgrounds.

7.5 Results of Heuristics Assessment

The parameters such as the accuracy of dimensions, joinery vertices, angle of the plane and alignments play a vital role in making a model successful. Heuristics analysis was conducted with 5 experts with a average of 10 years of design experience to ensure the usability of the instructional materials and the designed interface. Table 2 gives a summary of a heuristic study of VR and AR based Instruction concept which was adopted from Sutcliffe and Gault [9, 17].

The mean score given by experts for AR-based instructional medium is 4.18 which is better than the VR-based instructional interface (mean score = 3.12) indicates that AR is more appropriate for model making course. The heuristics results indicate that the AR-based concept achieved exceptionally well in the learning experience in terms of uniqueness of the concept, functionality, aesthetics of interface, visual feedback, and learnability. The inferences came out as the VR based instruction concept hasn't succeeded as much in the learning experience because of lesser visual feedback.

8 Conclusion

Strategies for AR-based instructions appear to be better suited to the required ease of learnability for model making courses. AR allows students to check for inaccuracies in the physical model. The overlay of the CAD model on top will be simple for AR. The study shows that AR-based guidelines offer a lot of value-added learning experience compared to VR-based concepts, because they are economically efficient and easily available. It provides an intended context for how well the physical model would fit into the surrounding environment. The AR introduces the aspect of assisting students to co-relate to the real world and iterate on their concepts without wasting a lot of material. This can help make industrial design education more environmentally friendly and sustainable over time. Immersive media extends the concept of receiving feedback beyond geographical boundaries, allowing students from all over the world to connect with faculties from anywhere in the world. To increase student engagement, voice user interfaces [17] can be combined with AR based interfaces.

There are also some limitations in the study that one has to keep in mind. VR/AR experience is reliant on internet speed and its availability. The interactions between faculty and students during online sessions would be influenced by internet speed. For simultaneous feedback on Immersive media, a faster internet connection is required. Even displaying the overlay of a virtual model on top of another model for comparison may take a long time if the internet connection is slow. User testing with an actual prototype with a design learner is limited in this study. Hence, the effectiveness of AR based instructions to learn model making can further be tested with industrial design students in near future.

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Innovative Ergonomic Product Development Process by Incorporating TRIZ into Human-Centered Design

T. Sakthi Nagaraj, H. Ganesan, and R. Jeyapaul

Abstract Modern markets desire innovative products and comfortable usage. Evidence revealed that a lack of methodology is to develop an innovative human-centred product. Human-Centered Design (HCD) was used to develop comfortable products, whereas Theory of Inventive Problem-Solving Technique (TRIZ) was used to develop innovative products. Hence, this study aims to develop an integrative methodology using the HCD approach and the TRIZ technique. The report demonstrates a new method, named Innovative Ergonomic Product Development (IEPD), which describes a systematic process to develop an innovative ergonomic product. The effectiveness of the developed IEPD methodology was ensured by a case study using industrial container design in the textile industry. Using IEPD methodology, a novel design was developed for an industrial container which ensured the innovation and ergonomic aspects. IEPD methodology helps researchers and/or practitioners to develop innovative ergonomic products systematically. The findings of the study help industries to develop innovative human-centred products.

Keywords Human-centered design · TRIZ · Ergonomics · Systematic product development · Industrial container design

1 Introduction

In the modern world, with maturing markets and customers becoming selective in innovative products and its comfortable use, businesses should focus on innovative and human-centred products. Many businesses have moved their emphasis

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to innovation and customer satisfaction in their products/services instead of technology/manufacturing. However, 70–80% of new product development failed due to customer dissatisfaction with products and not due to lack of advanced manufacturing and technology [1]. Currently, no single approach could tackle these issues simultaneously. Moreover, most available design approaches were entirely based on designers' knowledge and were unable to deliver optimal innovative design solutions.

Evidence highlights the significance of Human-Centered Design (HCD) in comfortable product development and that of the Theory of Inventive Problem Solving Technique (TRIZ) in innovative product development. Indeed, Human-Centered Design helps to develop user-centred products and improve commercial success. According to ISO 9241-210, "Human-centered design is an approach to interactive systems development that aims to make systems usable and useful by focusing on users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques". This approach counteracts possible adverse effects of use on performance, health and safety, and improves user satisfaction, accessibility, sustainability, effectiveness, efficiency and human well-being. HCD includes four phases such as understanding the system, identification of appropriate solutions and suggestions, creation of design solutions and evaluation of design solutions.

Moreover, to develop innovative products and solve problems of product development, the efficient TRIZ is used [2]. The resolution process consists of four successive steps. This technique converts a specific problem into a general problem by considering different combinations of 40 inventive principles in a 39×39 contradiction matrix (including 39 contradiction parameters). Subsequently, the inventive principles are extracted from the contradiction matrix, which provides general solutions for the general problem. Then these general solutions are converted into specific solutions for a specific problem [3].

Literature review of this study initially revealed the role of TRIZ in innovative product development processes and HCD aspects in ergonomic system development. Second, the lack of combined methodology to develop a product to meet both innovation and user-friendly features systematically. Hence, this study aims to develop an integrative methodology for an ergonomic innovative product development process. To achieve this, the objectives of the study are twofold: First, the development of an integrative methodology using the HCD and TRIZ. Second, demonstrate the developed model with a design of an industrial container. Therefore, the novelty of the study lies in the incorporation of TRIZ into HCD leading to a novel design in an industrial container. The study is of great relevance to researchers and practitioners in the field of new product development. Moreover, the study provides valuable information to develop innovative human-centred products.

The study has organised the paper as follows: Sect. 2 briefly reviews studies reported in the context of innovative product developments and ergonomic product development. Sections 3 describes the development of an innovative ergonomic product development methodology. Section 4 elaborately discusses the implementation of the developed methodology through design of an industrial container. Finally, Sect. 5 briefly discusses the results and concludes the study.

2 Research Background

2.1 Ergonomic Product Developments

Ergonomic aspects in product development ensure customer satisfaction through improved product reliability, operability, usability and safety. Consideration of ergonomic aspects in the early design phase ensures a pleasant product, but more time is needed to address data collection and analysis. Ergonomics in the late design phase leads to design iteration [4]. Moreover, in another study, Sun et al. [5] proposed a Function-Task-Behaviour framework to restate the design process by integrating human factors/ergonomics in the early design phase. The study attempted to develop a standard, less expensive and time-saving approach for designers. Lin et al. [6] applied ergonomic aspects in product development of over-bed tables for bedridden patients. The study focused on over bed tables in hospitals globally which help injured or disabled patients, but available tables do not meet their basic requirements. Quality Function Deployment (QFD) and virtual ergonomic analysis were used to develop a new ergonomic product design. QFD was used to match the customer requirement with technical requirements. The virtual ergonomic analysis ensured the absence of long-term injuries in wrist or lower back when using the ergonomically developed table. Zhang et al. [7] also proposed QFD with TRIZ for ergonomic product design and validated through a case study of innovative design for integrated kitchen stove in the early design stage. Also, Ghasemi et al. [8] developed a user-centred holder for an ultrasound transducer which ensured better wrist posture and comfort while working with the new holder. Specifically, Windrum et al. [9] highlighted the significance of ergonomic design in product innovation using the development of portable computers.

Most studies used the ergonomic aspect to develop human-centred systems and highlighted the significance of HCD. For example, Kuo et al. [10] used HCD to design a rifle. The study redesigned the buttstock shape, hand-guard, trigger handle shape, rifle weight and total length to improve shooting performance. Sotiralis et al. [11] focused on human-centred design aspects to develop a ship collision risk model by incorporating human factors. Boy [12] highlighted the significance of HCD in upcoming human missions to Mars. HCD highlighted context awareness as a key problem, which could be eliminated by defining scenarios through eliciting emergent cognitive functions and human-in-the-loop simulations. Recently, Gaspar et al. [13] proposed HCD methodology used in the marine industry to design a mooring winch and control station. The study focused on fatal accidents and severe injuries that occur during mooring operations and applied HCD to redesign control panel layouts. Especially, Human-centered aspects plays a vital role not only in industries' routine activities but also, in development of smart industries in the fourth industrial revolution [14]. Consideration of users' experience as a input of product design and developments ensures enhanced product quality and customer satisfaction [15].

2.2 Innovative Product Developments

Highly agile and competitive markets drive businesses to develop innovative products to ensure the survival and competitive advantages of an organization. Research highlighted the significance of innovative product design processes. In general, innovation occurs in three types of approaches as follows: First, innovative ideas occurred through flash of mind or sometimes accidentally. This approach is narrow as only a few are genius. The second is the empiric path approach which uses trial-and-error or brainstorming methods to develop innovative ideas. This approach fails to cover all possible solutions and is highly dependent on luck to get optimal innovation ideas. Third, the methodological approach is a systematic process for optimal innovative ideas [16]. Most researchers adopted the methodological approach to develop innovative products/processes.

TRIZ is a widely adopted and systematic innovation tool for developing innovative product design. Particularly, TRIZ makes conceptual design stage much easier than any other current methods [17]. Donnici et al. [18] integrated QFD and TRIZ to develop to design a hoverboard used for modern urban transport innovatively. QFD was used to indicate the technical characteristics necessary for the hoverboard, whereas TRIZ identified innovative project solutions. Similarly, Yamashina et al. [2] developed a framework by integrating QFD and TRIZ to develop technological innovation for new product development. The study confirmed the effectiveness of the integrated approach by using it in the technical innovation of a washing machine. Li et al. [19] developed a framework to develop product innovative design process using the TRIZ and Patent Circumvention. This framework has advantages of innovations development using or understanding ideas of a competitor's patent solutions. Chang and Huang [20] used TRIZ to solve technological problems that arise during the development of innovative products. The study integrated the workout and TRIZ to develop a novel bamboo-skin film applicable for in-mould injection moulding. Chou [21] integrated TRIZ with fuzzy linguistic evaluation techniques and concept mapping to generate innovative ideas of new product development through an air purifier design case study. To tackle issues of high cost and compressed time in machine tool industries, Hsieh et al. [22] incorporated TRIZ with decision-making trial and evaluation laboratory-based analytic network process (DANP) for the innovative design of machine tools. In this model, DANP acted as a decision support tool while TRIZ was a problem-solving tool when designing an innovative cover shape of machine tool.

2.3 Review Background Result

Most studies proposed QFD with HCD and TRIZ for ergonomic product development and innovative product development respectively. Though Pelt and Hey [23] revealed the opportunity for integrating HCD and TRIZ to develop consumer

products, limited studies have reported revealing the process to develop innovative ergonomic product design. Hence, the study aims to develop a novel methodology for developing innovative ergonomic products through the following objectives;

- To develop an integrated approach using TRIZ and HCD.
- To demonstrate developed IEPD methodology through an industrial container design.

3 Development of IEPD Methodology

As aforementioned, HCD consists of four phases such as understanding the system, identification of appropriate solutions and suggestions, creation of design solutions and evaluation of design solutions. The study incorporated TRIZ in the second phase of HCD approach to find innovative solutions and recommendations, as shown in Fig. 1.

The HCD approach consists of four phases. The first phase consists of a two-step approach, such as understanding the user context and identification of user requirements. For better understanding, the user context is divided into three domains, including the human, workstation and environment. The human phase in the system is observed in terms of physiological, psychological and cognitive characteristics. Similarly, work station phase is observed in terms of physical characteristics, force/weight required and safety, whereas the environment phase includes co-workers, supervisors, temperature, etc. In the second step, user requirements are identified by gathering information, identifying user needs, envisioning and evaluating probable solutions, and finally specifying the requirements. The first phase of HCD helps to understand the problems associated with human in terms of ergonomic aspects and their requirements.

In the second phase, the study integrated the TRIZ into the HCD approach for developing innovative appropriate design solutions and suggestions for identified ergonomic problems. The TRIZ technique consists of four steps in a resolution process such as deriving general solutions for ergonomic problem statements, identification of contradictions, deriving inventive principles from the contradiction matrix, and identifying specific solutions and recommendations. The TRIZ technique helps to develop innovative design solutions and suggestions for the identified ergonomic problems.

The third phase of HCD incorporates the solutions and suggestions into product design. The proposed product design is iterating until it meets the user requirements. The fourth phase of HCD evaluates the design to develop final products that ensure user requirements. Then, the developed IEPD methodology was demonstrated through a case study for industrial container redesign.

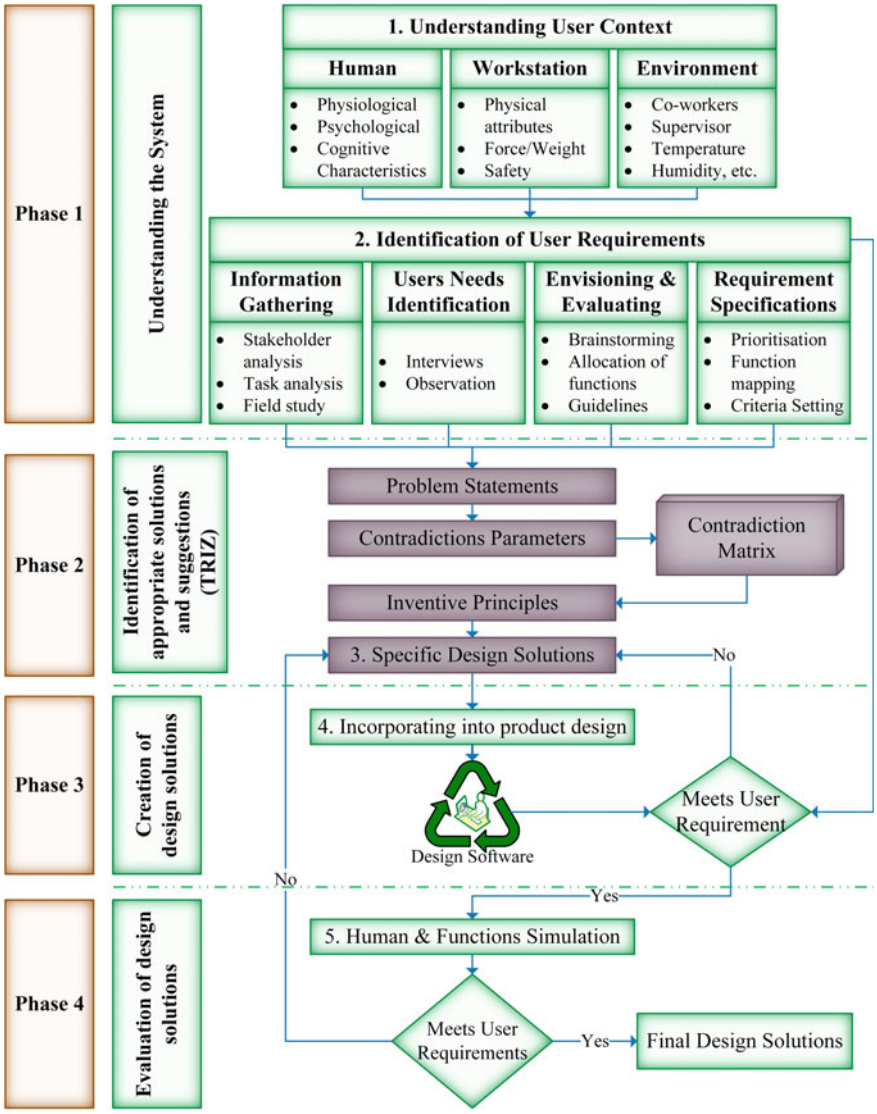

Fig. 1 A novel methodology of innovative ergonomic product development (IEPD). *Note* The TRIZ steps are highlighted in brown color

4 Case Study

4.1 Case Study Description

The case study was conducted to demonstrate the developed IEPD methodology in collaboration with a large-sized Sri Lankan textile industry. The textile industry was selected as it had significant human interaction and poor working conditions with different systems [24, 25]. To conduct the case study effectively, a steering team including a researcher, two industrial engineering executives and six team leaders was farmed.

The case study focused on the redesign of an industrial container (input bin) used to store, transport and distribute cut panels to the sewing floor from the cutting department in the textile industry. On the sewing floor, bins are used to distribute bundles one by one to sewing module. The sewing module's team leader is involved in feeding the cut panels into the module. The feeding operation consists of opening the bin, selecting a specific bundle, closing the bin, checking the quality and quantity of cut panels and feeding them into the first operation in the sewing module. The feeding operation affects workers' physical and mental health, and performance significantly. The redesigning user-centered industrial container helps eliminate the negative effects of the feeding operation. Hence, the case study aims to demonstrate the IEPD methodology by redesigning the user-centered industrial container.

4.2 Implementation of IEPD Methodology for Industrial Container Redesign

Understanding the System

Initially, the study observed that one male helper and a female team leader were involved in the loading and transporting operations. In the sewing module, a co-worker was needed to help the team leader open/close the container lid. Similarly, a male helper was involved with her to clean, dismantle and return the empty container. The container was considered as a workstation for the feeding operation and consisted of opening the bin lid, picking right cut bundle from the bin, closing the lid, checking quantity and quality of cut panels, accounting type and number of defective panels and replacing them to complete the job order. These activities affect the physical and mental health of the team leader. The physical parameters of the container are; height 1 m, length 1.6 m and width 1.3 m. The container consists of three parts (top, bottom and side walls) and weighs around 12 kg. The team leader is exposed to cotton dust during bundle handling activities.

Second, based on the collected information, the user requirements such as accessibility up to the container's bottom, easily opening the lid by one worker, ease of transport, storing and cleaning, and same capacity were identified. Subsequently, based on the requirements, the study envisioned and evaluated a few suggestions like using

a height-adjustable bin wall, having weightless lids, rollers on the bottom and using a honeycomb design. In the fourth step, functional requirements as unfolding the bin, updating job details, checking and loading cut bundles, transporting it to the sewing module, checking quantity and quality of cut panels, updating type and number of defective panels, feeding right cut panels into module, cleaning and returning empty bin to store. The problems associated with industrial container usage in textile industry was revealed by Sakthi Nagaraj et al., in 2019 [24] through their ergonomic evaluation study. The observed problems were as follows;

- Awkward posture during bundle handling.
- Physical strain during bundle handling, closing and opening the lid and transporting the bin.
- Increase in mental workload during quality and quantity checking of cut panels and accessories and, job file handling and order completion processes.

Identification of Appropriate Solutions and Suggestions (TRIZ)
In this phase, the study used TRIZ to locate innovative design solutions and suggestions to develop a new design for the input bin. It consists of four successive steps and were applied when developing design solutions for the input bin as follows;

Step 1: General description of the problem.

Indeed, a well-defined problem is half-solved. The previous phase revealed the ergonomic issues associated with input bin and the user's requirements. To solve ergonomic problems of the workers who participate in the feeding operation, at least, one or more of the following features should be incorporated into the input bin: less height for bin walls, less weight for bin lid, less complexity in ensuring quality and quantity of cut panels and job file update. If one of these features is altered this can lead to a deterioration of features called technical contradictions. It is necessary to highlight the contradiction parameters which prevent solving the problem. The problem is that of enhancing the ergonomic aspects by optimizing technical contradictions that worsen the situation.

In this step, the study derived a general problem as follows:

- *Reducing the height of bin wall with the same capacity and shape.*
- *Reducing the weight of the lid with adequate strength.*
- *Reducing the work pressure with lesser human error.*
- *Reducing the mental workload with better accuracy of job file updating task.*

Step 2: Formulation of problem in terms of 39 technical contradiction parameters.

Based on the general description of the problem statements, it is possible to translate problem in terms of technical contradictions. By answering the following questions; "(1) What should be enhanced? (2) What will worsen? (3) Which system feature should be improved? (4) Which system feature will worsen?", conflicting parameters can be identified. Based on this, the general description of the problem was converted in terms of technical contradiction as follows;

- Reduced ***height*** of bin wall while decreasing the ***capacity*** of the bin ***(4–8)***
- Reducing ***weight*** while decreasing the ***strength*** of the bin lid ***(14–2)***
- Reduced work ***pressure*** while increasing process ***reliability (27–11)***
- Reduced mental ***workload*** while increasing measurement ***accuracy (28–11)***

Steps 3: Formulation of general solutions from 40 inventive principles.

Problems in terms of technical contradictions help identify corresponding inventive principles to eliminate technical contradictions. The inventive principles develop general solutions for the general problem.

• (4–8) = 35–8–2–14	• (27–11) = 10–24–35–19
• (14–2) = 40–26–27–1	• (28–11) = 6–28–32

Step 4: Formulation of specific solutions for input bin design.

The general solutions, i.e., inventive principles can be converted to specific solutions for input bin design. General inventive principles were sorted for input bin design by brainstorming with team members. The selected appropriate inventive principles were translated to design solutions as follows;

(a) First contradiction and design solutions: Inventive principles in the first contradiction were parameter changes, anti-weight, taking out and spheroidality—curvature. Anti-weight was not suggested for the first contradiction and the remaining were accepted as design solutions. The taking out principle was adopted by which the team decided that the front and back side bin walls should open/close at the bottom to ensure easy access of bundles from the bin bottom. Another principle, parameter changes, was adopted by which rubber stoppers were used in the bin's bottom and side walls to ensure noiseless close/open operations. Spheroidality—curvature principle was adopted to provide rollers at the bottom of the bin to ensure ease of transportation.

(b) Second contradiction and design solutions: To eliminate the second contradiction, the inventive principles such as composite materials, copying, cheap short-living objects and segmentation were suggested. Copying and cheap short-living objects were not suggested for the second contradiction. Composite materials were suggested for manufacturing the new design of input bin. By adopting the segmentation principle, the bin's side walls, bottom and lid should be easy to assemble/disassemble by providing latches. Besides, sliding mechanism was provided to ensure the lid's sliding and rotary motion.

(c) Third contradiction and design solutions: The suggested inventive principles were periodic action, preliminary action, intermediary and parameter changes. First three appropriate inventive principles were considered for specific design solutions. The periodic action principle lead to introduction of short breaks in between feeding operations. By adopting the preliminary action principle, the Kanban card was introduced to store the remaining cut panels in a garment and damaged panels separately which results in ease of completing job order.

Also, intermediary principle lead to the provision of two small bins available in market similar to dust bins should be temporarily attached to the input bin for storing cut panels with Kanban cards.

(d) Fourth contradiction and design solutions: To eliminate the fourth contradiction, inventive principles such as universality, mechanics substitutions and colour changes were adopted. The universality principle lead to the provision of an elevated stage in front of the bin to ensure that the bin lid was below the elbow level. By adopting mechanics substitutions principle, the front wall was provided with a slot for a smart screen which will act as an input device for Computer Aided Manufacturing System (CAMS) for replacing job file. Based on user requirements, the colour changes principle was adopted for easy cleaning, by adopting a honeycomb structure for the bin's bottom and side walls.

Creation of Design Solutions

Based on the feedback of stockholders and team members, a few corrections were made and a detailed design was developed using the Siemens NX Design software as shown in Fig. 2.

Figure 2a represents the design features whereby the bin is foldable and portable by workers without additional aid. Figure 2b represents a closed bin whose lid can be

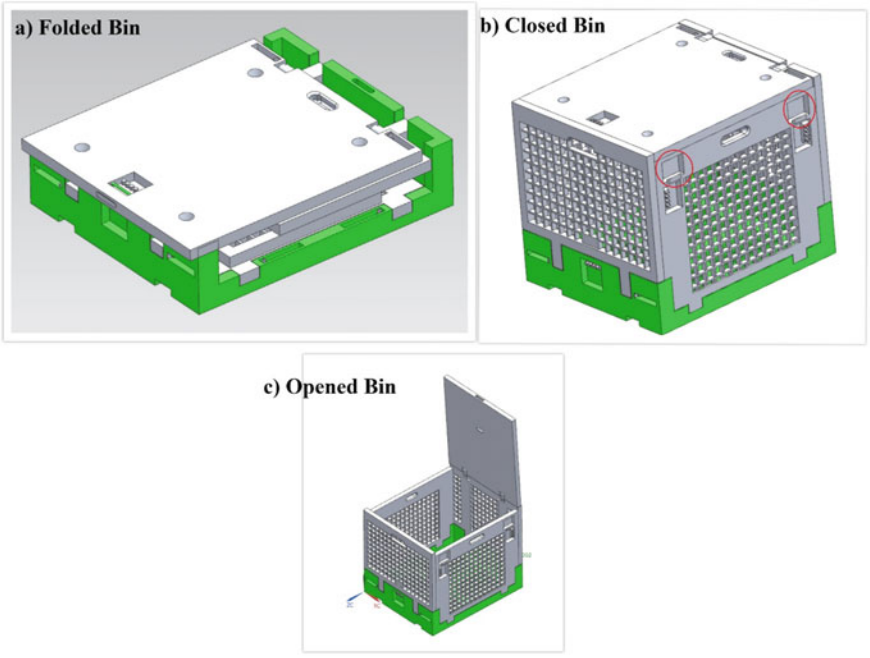

Fig. 2 Detailed design of input bin

opened by sliding the front and back, thereby eliminating taking out of the lid when opening the bin. The sliding feature saves time and additional worker requirements. By unlocking the latches on the lid, the lid can slide front and back and when it is locked the lid can be opened as shown in Fig. 2c. A smart device slot was provided in the front wall and highlighted by red colour circles as in Fig. 2b. The device is allocated to replace the job file and aids workers in computing and reordering cut panels for completing the job order. The bin's bottom is provided with a honeycomb structure and four wheels, which ensure ease of cleaning and transportation respectively. The dimensions of the bin were not changed in the design solutions. In the design solutions, the two small bins were not disclosed as they are available in the market.

Evaluation of the Design Solutions

The evaluation phase of HCD focused on ergonomic assessment for the most critical activity such as accessing the bundle. Once the design solutions met user's requirements, the study evaluated them using SIEMENS Human Modeling and Simulation software. Highly critical activity such as picking bundles from the bin was selected and analyzed. Figure 3a represents the posture of the worker picking bundles from a maximum reach level. Beyond this, the design permits workers to open front or back sidewalls for easy access. Moreover, Fig. 3b represents the most critical location to access. This design permits entry into bin for ease of accessing the bundles. For this activity, the worker experienced total cumulative compression/shift around 9.99 MNs (including loading incurred during active work and idle time) which was within the threshold value (22.50 MNs). Hence, the final design solution ensured the safe use of the industrial container. The final design solutions satisfied user requirements and resolved the ergonomic issues associated with the industrial container.

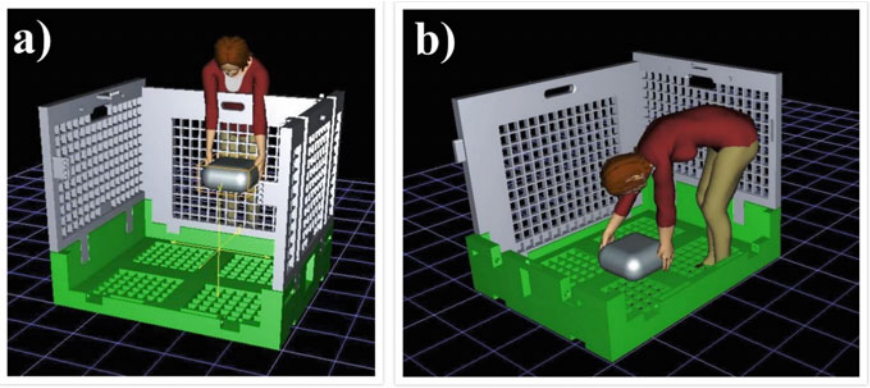

Fig. 3 Human simulation for critical reach zone of closed (**a**) and opened (**b**) wall positions

5 Conclusions

The study proposed an integrative methodology for new product development using the HCD approach and TRIZ. The developed methodology was named as "Innovative Ergonomic Product Development (IEPD)" with which the researchers and/or practitioners can systematically execute product development from product planning to development of design solutions. By attempting the derivation of ergonomic innovative ideas for industrial containers using IEPD methodology, the study demonstrated a systematic process sequence to develop a human-centered innovative product. In addition, the study established largely abolished physical and psychological strain in the case of ergonomic innovative idea derivations, as TRIZ was concretely and systematically employed in the identification of innovative design solutions for the industrial container. Findings of the study highlighted that the developed IEPD model was effectively demonstrated through improved design of the industrial container. The developed methodology, IEPD can be expected to provide innovative ergonomic design solutions and also evaluate derived ergonomic design solutions effectively. Finally, the study established the possibility of deriving ergonomic innovative ideas in IEPD and contributing to the development of human-centered innovative products having market influence. The study fills the gap in the literature in the context of new product development and delivers a noteworthy opening to take product development literature forward in developing innovative human-centered products. Moreover, it opens a new window for researchers to validate the IEPD model to process design and thereby ensure for ensuring human-centered innovative process development.

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Ergonomic Risk Factors Associated with Pineapple Harvesting Task in Northeast India

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Abstract Manual pineapple harvesting is one of the most critical and challenging tasks in pineapple farming. This study assessed the ergonomic risk factors associated with pineapple harvesting task in northeast India. A total of 152 pineapple farmworkers (92 males and 60 females) were studied using the standard Nordic Questionnaire for musculoskeletal symptoms (MSS) and direct observation. Rapid Entire Body Assessment (REBA) tool was employed to assess the key working postures adopted during the harvesting task for a sub-set of the respondents (12 males and 8 females). The present study found that MSS was highly prevalent (79.61%), and low back (76.32%) was the most affected body part among the farmworkers. The work postures with high-risk score of 8–10 (action level 3) and very high-risk score 11 or more (action level 4) were 30% and 70%, respectively. This study also highlighted a high-risk score of 8–10 (action level 3) for more than 80% of the participants during the pineapple loading task for local transportation. Farmworkers were exposed to various ergonomic risk factors, which include awkward work postures, repetitive tasks, heavy load carrying, and improper rest-pause might be linked to the prevalence of MSS among the farmworkers. Moreover, walking uphill or downhill on hilly terrain during the harvesting imposed an additional burden on the farmworkers. Based on the results, there is an urgent need to explore effective preventive interventions suited to local conditions for improving the working conditions and occupational wellness of the pineapple farming population in northeast India.

Keywords MSDs · Fruit harvester · Posture · Load carriage · Hilly terrain · Discomfort · REBA

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1 Introduction

Pineapple is cultivated commercially in almost all the states of northeast India. Among the major fruits in the region, pineapple ranked 2nd (19.91%) after banana (30.32%) in terms of production, and 3rd (15.72%) after citrus and banana in terms of area under fruit cultivation during 2013–14 [1]. Northeast India also contributed more than 40% of total pineapple production in India [2–4]. Moreover, out of eight states in northeast India, six of them had been placed consistently among the top ten pineapple producing belts of the country [3]. Although pineapple is an important crop, it is also a very challenging crop in terms of associated risk factors for human labour involved in its production processes [5]. Among the processes, harvesting is very critical, high labour requirement, and time-consuming process. It is usually done manually using small hand tools. Though there is scope of improved and large machines in developing countries for pineapple harvesting, it is not applicable in India and northeast India in particular due to inherent constraints of the region, such as difficult hilly terrain, small farm size, land tenure systems, traditional ways of cultivation practices, etc.

As pineapple grows on the ground, farmworkers have to bend down while harvesting and it also induces easy injuries to farmworkers because of the spines and leaf tips [6]. A study in Malaysia reported 87.0% prevalence of musculoskeletal symptoms (MSS) and the most prominent symptoms was at low back (64.8%) [7]. Moreover, the harvesting task was reported to be the most risky task in terms of health hazards and safety issues. Similar studies have also reported occupational hazards due to work stressors such as awkward postures, repetitive tasks etc., and use of improper tools and techniques for Malaysian oil palm fruit harvesters [8], Cambodian fruit farm workers [9], Iranian apple harvesting laborers [10], Brazilian banana harvesting workers [11]. From the literature, it is noticed that there is a lack of studies on ergonomic risk factors or stressors associated in pineapple harvesting in the context of India. Despite the high-risk potential of occupational health and safety issues among the pineapple farmworkers, no previous studies have been reported from any parts of India. Therefore, it was aimed to investigate ergonomic risk factors associated with pineapple harvesting task in northeast India.

2 Materials and Methods

2.1 Study Area and Data Collection

This study was carried out during June to November, 2019 from the top three pineapple growing states in Northeast India (Assam, Manipur and Meghalaya). From these states, seven districts (two from Assam, three from Manipur, and two from Meghalaya) were purposively selected based on area, cultivation practice, and proximity. Then, a minimum of two pineapple growing villages from each district were

purposively selected. Finally, the villagers were randomly invited and identified based on inclusion criteria of the study. A farmer of age 18 years or older, who had no history of accidents or any chronic disease, and involved in pineapple farming for at least one year were considered as a sampling unit. The study was conducted on a total of 152 pineapple farmworkers (92 males and 60 females). MSS data was collected using the standard Nordic Questionnaire developed by Kuorinka et al. [12].

2.2 Postural Analysis

During the study, a sub-set of farmworkers (12 males and 8 females) was involved for postural analysis by REBA method to identify the potential risk postures adopted by the pineapple farmworkers that could contribute to prevalence of MSS among the farmworkers. For this analysis, the pineapple farmworkers were observed and recorded their work postures while carrying out their farm activities at their respective farms. Then, the REBA score was calculated using the REBA body part diagrams and REBA score sheet. The REBA score ranges between 1 and 15. A REBA score 1 suggest that the risk is negligible, meanwhile a score between 2 and 3 suggest a low risk and changes may be needed; REBA score of 4–7 indicates a medium risk and changes are needed; REBA score of 8–10 indicates a high risk, in which investigation is needed to implement changes; and lastly, a REBA score of 11 or more suggest a very high risk and changes are needed immediately. Descriptive statistics was used to summarize and interpret the MSS data and REBA scores for various body parts of the participants in the study.

3 Results and Discussion

3.1 Job Description

In the harvesting process, the farmers had to dress up properly before entering the plantation: long pant/trouser, full sleeve shirt, hand gloves and jungle boot to avoid injury from pineapple leaf tips and spines. After properly dressed, the farmers entered into the pineapple plantation along the rows one after another to harvest the ripe pineapple fruits. With a bamboo basket strapped over their shoulders/heads or a gunny bag in their hands, farmers had to select and harvest the ripe fruits (one at a time) by breaking it with hand or cutting it with a tool. The hand tools used for pineapple harvesting were local sickle (*Rasi* in Khasi and *Thangol* in Manipuri), *dao* and kitchen knife sometimes. These hand tools were used for multiple purposes. They were locally evolved traditional tools and were not designed from ergonomic perspective. Then, the harvested fruit was placed inside the bamboo basket or gunny bag and continued until the basket or bag was filled with harvested fruits. The basket

or bag with fruits was then emptied and fruits get collected at a place within the farm itself for further transportation. The same process continued until the target fruit numbers were harvested. For any type of work, all the respondents were found using locally evolved indigenous hand tools, such as a sickle, knife, spade, and different designs of short and long-handled machetes. Approximately 87.50% of the respondents worked for ≤6 h (average: 4.73 h) a day which was relatively less as compared to 6–7 h in other major pineapple producing counties, such as Malaysia as reported by Rani et al. [7]. Moreover, the farmworkers in northeast India were not habituated to follow any pre-defined work-rest schedule. Therefore, the farmworkers reported random breaks as and when required during their working hours.

After the harvest, fruits were collected at a place within the pineapple farm. At this place, optional post-harvest operations such as crown thinning, maintaining a proper stalk and sorting of fruits took place before transportation. Then, the fruits were loaded in bamboo basket or gunny bags for transportation. In the northeast India, pineapple farms were mostly located at far-flung hill slopes (more than 94%) and foothills. Therefore, local transportation of harvested pineapple fruits comprised of two stages. The first stage of local transportation took place between the collection point at production place and a transit place. In the first stage, farmers had to walk downhill or walk on foot for a distant up to 500 m carrying bamboo basket or gunny bag filled with fruits (40–50 kg) on their head. A transit place may be the foothill, farmers' house, or village roadside. The second stage of local transportation took place between the transit place and the local or distant market either by bicycles, two-wheelers, rickshaws or four-wheelers.

3.2 Musculoskeletal Symptoms (MSS)

The prevalence of MSS among the pineapple farmworkers is presented in Table 1. The results show that the prevalence of MSS reported on one or more body parts over the last 12 months was 79.61%. The body parts with highest prevalence of MSS was low back (76.32%) followed by neck (46.71%), shoulders (46.05%), knees (33.55%), and wrists/hands (27.63%). A similar study in Malaysia reported a higher rate of overall MSS (87%) and low back being mostly affected body part (64.8%) [7]. Moreover, various other studies also reported more or less similar scenarios of MSS among agricultural workers—oil palm harvesters [8], manual rice harvesters [13, 14], apple harvesting laborers [10], and fruit farmworkers [9], and agricultural workers in general [15, 16]. Previous researchers reported that the low back was the most affected site among all body parts, which is in line with this study [7–10, 13–16].

Due to the MSS, the farmworkers had reported disruption of normal activities (65.13% of respondents) during the last 12 months. The pain intensity was highest in the back. Even some farmworkers reported medication for low back pain. This result suggested highly prevalence of MSS among pineapple farmworkers in northeast

Table 1 MSS among pineapple farmworkers in north east India (N = 152)

Body part	Prevalence of MSS		Disruption of normal activities due to MSS	
	(Last 12 months)		(Last 12 months)	
	Frequency	Proportion (%)	Frequency	Proportion (%)
Neck	71	46.71	55	36.18
Shoulder	70	46.05	53	34.87
Elbows	23	15.13	17	11.18
Wrists/hands	42	27.63	33	21.71
Upper back	17	11.18	12	7.89
Low back	116	76.32	89	58.55
Hips/thighs	12	7.89	9	5.92
Knees	51	33.55	42	27.63
Ankles/feet	23	15.13	18	11.84
Any body part	121	79.61	99	65.13

India. Moreover, problems like itchiness and injuries on various body parts due to spines and leaf tips of the pineapple plant had also been reported.

3.3 Postural Analysis and Risk Factors

In this analysis, the pineapple-harvesting task was divided into two sub-tasks: sub-task 1 (pineapple harvesting and collection) and sub-task 2 (local transportation). From these two sub-tasks, the key potential risk postures were identified and analyzed using REBA as shown in Figs. 1 and 2. The number and percentages of participants with REBA scores (Score A for neck, trunk and legs and Score B for upper arms, lower arms and wrists) are given in Tables 2 and 3. The upper arm mean scores of 2.95 and 3.5 indicated a flexion between 45 and 90° in harvesting task and slightly abducted and more flexed upper arm (>90°) during pineapple loading task for local transportation, respectively. The mean score of lower arms below 2 in both sub-tasks indicated the lower arms movement in the range of 60–100°. The wrists score of 3 indicated a twisted/deviated wrist with more than 15° flexion in sub-task 1, while a general wrist score of 1 in sub-task 2 showed a normal wrist flexion/extension of 0–15° without any twist/deviation. The neck and trunk score of 2 and between 3 and 4, respectively for the majority of the participants highlighted that the farmworker was in flexion more than 20° to the front. Lastly, the legs score more than 2 indicated a stressful position due to awkward bending postures while performing the tasks. It was also found from the grand REBA score that the postures adopted with high-risk score of 8–10 (action level 3) and very high-risk score of 11 or more (action level 4) were about 30% and 70%, respectively in sub-task 1. Whereas, a REBA score of

Fig. 1 Postures adopted during pineapple harvesting and collection

Fig. 2 Postures adopted during loading fruits for local transportation

8–10 (action level 3) was found for more than 80% of the farmworkers in sub-task 2. The result are in lined with the findings of the study conducted in Malaysia by Rani et al. [7] in which 23.8% for high risk score and 76.8% for very high risk score were reported in pineapple harvesting in Malaysian conditions.

The farmworkers were also exposed to several ergonomics risk factors (forceful exertions, highly repetitive motion, excessive bending, prolonged stooping, heavy

Table 2 REBA scores of sub-task 1 (pineapple harvesting and collection) for different body regions (N1 = 20)

REBA score	Body parts N1 (%)								
	Upper arms	Lower arms	Wrists	Neck	Trunk	Legs	Score A	Score B	Grand score
1	2 (10)	2 (10)	–	3 (15)	–	–	–	–	–
2	2 (10)	18 (90)	–	17 (75)	1 (5)	13 (65)	–	–	–
3	11 (55)	–	20 (100)	–	11 (55)	5 (25)	–	–	–
4	5 (25)	–	–	–	8 (40)	2 (10)	–	3 (15)	–
5	–	–	–	–	–	–	1 (5)	1 (5)	–
6	–	–	–	–	–	–	5 (25)	11 (55)	–
7	–	–	–	–	–	–	8 (40)	–	–
8	–	–	–	–	–	–	5 (25)	5 (25)	–
9	–	–	–	–	–	–	1 (5)	–	3 (15)
10	–	–	–	–	–	–	–	–	3 (15)
11	–	–	–	–	–	–	–	–	5 (25)
12	–	–	–	–	–	–	–	–	9 (45)
13–15	–	–	–	–	–	–	–	–	–
Weighted mean score	2.95	1.9	3.0	1.85	3.35	2.45	7	6.15	11

Note Score A (combined score for neck, trunk and legs) and Score B (combined score arms and wrists)

Table 3 REBA scores of sub-task 2 (loading for local transportation) for different body regions (N2 = 8)

REBA score	Body parts N2 (%)								
	Upper arms	Lower arms	Wrists	Neck	Trunk	Legs	Score A	Score B	Grand score
1	1 (12.5)	2 (25)	8 (100)	2 (25)		2 (25)	–	1 (12.5)	–
2	–	6 (75)	–	6 (75)		6 (75)	–	–	–
3	2 (25)	–	–	–	1 (12.5)	–	–	–	–
4	4 (50)	–	–	–	7 (87.5)	–	1 (12.5)	3 (37.5)	1 (12.5)
5	1 (12.5)	–	–	–	–	–	3 (37.5)	3 (37.5)	–
6	–	–	–	–	–	–	4 (50)	1 (12.5)	–
7	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	2 (25)
9	–	–		–	–	–	–	–	4 (50)
10	–	–	–	–	–	–	–	–	1 (12.5)
11–15	–	–	–	–	–	–	–	–	–
Weighted mean score	3.5	1.75	8.0	1.7	3.9	1.75	5.4	4.25	8.25

Note Score A (combined score for neck, trunk and legs) and Score B (combined score for arms and wrists)

load carrying etc.) during the pineapple harvesting task in northeast India as presented in Table 4. During the harvesting task, a farmworker could harvest about 150 fruits per hour on an average and harvesting session continued for 4–5 h in a day. The risk factors might be linked to the prevalence of MSS among the pineapple farmworkers which is in line with the studies reported by Rani et al. [7, 17]. Moreover, other aspects of the working environment such as walking uphill or downhill on uneven hilly terrain during the harvesting task imposed an additional burden on the farmworkers. Therefore, this study suggested an urgent investigation to implement necessary changes for improving working conditions and occupational wellness of the pineapple farmworker in northeast India. It is believed that introduction of innovative and sustainable interventions might help in reducing ergonomic risks factors. McMillan et al. also suggested that structured interventions could be engineering changes or behavioral modifications. Though effective implementation of behavioral changes is very challenging, the motivated workers might adopt it to reduce their risk of MSS [18].

Table 4 Ergonomic risk factors in pineapple harvesting task

Sub-activity in harvesting	Risk factors	Possible consequences
Harvesting and collection	Forceful exertion on shoulder	Shoulder pain
	Highly repetitive deviation and twisting of wrist from neutral position (>20 times in a minute)	Wrist pain
	Excessive bending posture during harvest	Low back pain
	Carrying heavy load (40–50 kg uphill or downhill at a time, a total of 400–500 kg in a day)	Pain at neck and low back
	Prolonged stooping during unloading of pineapple from the basket/gunny bags at collection point	Low back pain
Transportation to a local transit point from the collection point	After completion of harvest session, prolonged stooping during loading of pineapple into the basket/gunny bag with or without post-harvest operations	Low back pain
	Carrying heavy load (40–50 kg downhill at a time, a total of 400–500 kg in a day to the transit point away from the farm)	Pain at neck and low back pain

4 Conclusions

This study highlighted that the pineapple farmworkers were exposed to various ergonomics risks, which include awkward work posture, repetitive tasks, heavy load carrying on their head, and improper rest-pause might be linked to the prevalence of MSS among the pineapple farmworkers. The present study also highlighted that the highly prevalence of MSS (79.61%) and the prominent part of body affected was low back (76.32%) among pineapple farmworkers in northeast India. The postures adopted during the pineapple harvesting task with high-risk score of 8–10 (action level 3) and very high-risk score 11 or more (action level 4) were about 30% and 70%, respectively. This study also highlighted a high-risk score of 8–10 (action level 3) for more than 80% of participants during the pineapple loading task for local transportation. Moreover, walking uphill or downhill on uneven, hilly terrain during the harvesting task imposed an additional burden on the farmworkers. Therefore, the present study suggested that there is an urgent need to explore effective preventive interventions suited to local conditions for improving the working conditions and occupational wellness of the pineapple farmworker population in northeast India.

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Drudgery Estimation in Walking Behind the Power Tiller During Field Operations

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Abstract To calculate the drudgery involved in walking behind the power tiller, six experience power tiller operators were selected as subjects and calibrated in the laboratory. The heart rate (HR) of the selected subjects was measured during puddling and tilling operations. The HR of fellow person who was just walking behind the power tiller at the same speed and path was also measured to evaluate the effect of hand vibration and noise. The measured HR was used to calculate the oxygen consumption through calibration curve and further Energy Expenditure Rate (EER) was calculated. It was observed that the average HR, volume of oxygen consumed (VO_2) and EER of the operator during puddling were 10.08, 23.10, and 10.91% higher than tilling. Further, the average HR of fellow person was 11.26 and 13.15% lower than operator during puddling and tilling, respectively.

Keywords Walk behind power tiller · Heart rate · Energy expenditure rate · Volume of oxygen consumed

1 Introduction

Power tiller is the most promising power source for agricultural operations at the level of small and medium farmers. More than 85% of farmers of North-Eastern India fall under small and marginal land holding category, therefore, making the power tiller the most suitable farm power source for this reason. Power tiller is used mainly for seedbed preparation during tilling and puddling operations. It is also known as a hand tractor or walking type tractor because the operator has to walk behind the machine during the operation. The main job of the power tiller

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operator is to operate the steering clutch at the turning. To do so, the operator has to walk behind the tiller in puddle soil throughout the period which amounts to a huge level of drudgery. As per an estimate, an operator has to travel 15–20 km for tilling one-hectare land with a rotavator of 0.60 m width [1]. The walk-behind during puddling is more difficult which takes approximately 10 h to complete one-hectare land. During puddling operation, walking in the saturated field for a long time leads to an increased in the level of fatigue [2]. Operators are also exposed to hand-arm vibration while holding the handles continuously and the noise level of the machine adds further level of fatigue. Many researchers [2–7] has studied on power tiller mainly on noise and vibration but very limited work has been reported on operator's drudgery [8, 9]. The growing migration of agricultural labor to cities and the rise in labor rates are not the only reasons for the accelerated mechanization of farm operations. Factors such as time saving, efficient input application, transportation of farm inputs and produce, and reducing drudgery also stimulate demand for farm machines. Economic advantages and control capacities of power tillers in various conditions and roads lead to an expansion in utilizing these tractors transportation of agricultural products and human beings in fields and rural roads [4, 6]. Still, the power tiller is not fully adopted by many farmers in India with small land holdings is due to the drudgery involved in its operation. A scientific study for evaluating the human drudgery involved in power tiller operation will help in scheduling the work-rest schedule as well as the maximum working period to save the operator from musculoskeletal disorder. This will also help the power tiller manufacturer and associated scientist for design modification in the existing design. Hence, the aim of this study was to known the oxygen consumption and energy expenditure rate in operating the power tiller.

2 Materials and Methods

The drudgery calculation was mainly based on the measurement of heart rate (HR), VO_2 and energy expenditure rate (EER). The HR was measured in the field and VO_2 was calculated based on subject calibration in the laboratory. Further, EER was calculated based on calculated VO_2.

2.1 Selection of Subject

Six healthy subjects of North Lakhimpur District of Northeastern state Assam who had experience of at least 3 years in power tiller operation were chosen for the study. Initially, subjects were screened and excluded from the study if they had reported any past or current major surgeries or any other major sickness. Each subject had been intimated the purpose of this study and written consent was obtained prior to the

Table 1 Physical characteristics of the selected subject

Subject	Age, years	Stature, cm	Weight, kg	BMI	Experience, years
S1	29	150	44	19.6	6
S2	43	151	48	21.1	5
S3	45	159	41	16.2	4
S4	46	156	47	19.3	5
S5	36	164	65	24.2	7
S6	31	160	66	25.8	4
Mean	38.33	156.67	51.83	21.03	5.17

Fig. 1 $K4b^2$ complete unit

experiment. The subjects were advised not to take any intoxicants from the previous night. The demographic feature of the selected subject is given in Table 1.

2.2 Subject Calibration

The selected subjects were calibrated under controlled environmental conditions. The subjects were given ample time to familiarize with the tread mill and the instruments used in the experiment. The exercise was performed on a motor driven Track master TMX425 treadmill. The aerobic response (oxygen consumption) was measured by the ambulatory metabolic measurement system, Cosmed k4b2 (Italy). The instrument consists of portable unit, telemetry unit and battery unit as shown in Fig. 1. Before the test, the portable unit was calibrated for delay, turbine and gas. For gas calibration, the cylinder having a composition of 4.95% of carbon dioxide (CO_2), 16.05% of oxygen (O_2) and rest nitrogen was used. The results of calibration should be within the acceptable range. Prior to conducting the experiment, the portable unit was warmed up for 45 min as it uses O_2 and CO_2 sensor. A polar heart rate monitor was used to measure the heart rate during the calibration.

The sub-maximal test was performed to determine the maximum aerobic capacity of the selected subjects following Naughton protocol [10]. Each subject was allowed to walk on the treadmill and incremental load (in terms of speed and inclination) was driven at an interval of 3 min. The experiment was continued till the heart rate reached 75% of maximum heart rate which was calculated using Robergs and Landwehr equation [11] i.e., $HR_{max} = 205.8 - 0.685 * Age$ as shown in Fig. 2. The HR and VO_2 were recorded and a regression equation was developed. The developed regression equation is known as calibration curve which was used to estimate the VO_2 with reference to measured HR in the field. Further, the calibration curve was extrapolated till the maximum HR. The extrapolated VO_2 corresponding to HR_{max} was considered as VO_{2max}. A sample extrapolated curve between HR and VO_2 for calculating VO_{2max} is shown in Fig. 3.

Fig. 2 Calibration of the subject in the laboratory

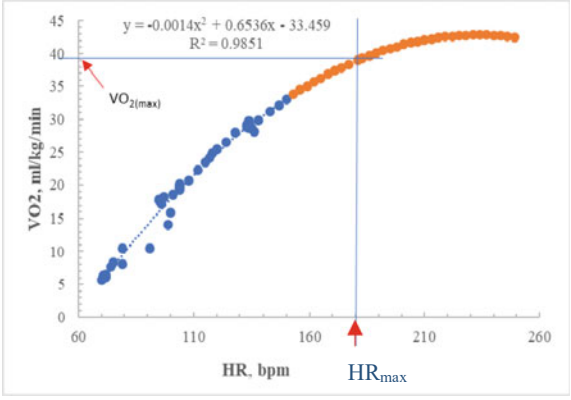

Fig. 3 A sample curve plotted between HR and VO_2 for sub-maximum exercise

(a) Puddling

(b) Tilling

Fig. 4 HR measurement during puddling and tilling with a fellow person

2.3 HR Measurement During Field Operations

The heart rate of the selected subject was recorded by polar heart rate monitor (RS 400) with wrist band. To find the effect of vibration and noise of the machine, a fellow person was asked to walk behind the operator at the same speed during the field operations of power tiller. The heart rate was measured for puddling and tilling operations as shown in Fig. 4. The data were taken for 30 min. Prior to experiment a rest of 15 min was given to bring the heart rate to normal range. After the experiment, a rest was given until the heart rate reached to the normal value. From the recorded average working heart rate, the volume of oxygen consumption was estimated from the calibration curve. Further, the energy consumption for operating the power tiller for puddling and tilling operations were calculated after finding the oxygen consumption using Eq. 1.

$$\text{EER} = (\text{O}_2 \text{ consumption in liters} \times 4.8) \text{ kcal} \tag{1}$$

3 Results and Discussion

3.1 Calibration

The subject-wise calibration equation, their HR_{max} and VO_{2max} is given in Table 2. The average HR_{max} and VO_{2max} were found to be 180 bpm and 40.26 ml/kg/min, respectively.

Table 2 Subject wise calibration curve with HR_{max} and VO_{2max}

Subject	Calibration equation	R^2	HR_{max}, beats/min	VO_{2max}, ml/kg/min
S1	$y = -0.0014x^2 + 0.653x - 33.459$	0.985	182	45.61
S2	$y = -0.0015x^2 + 0.678x - 40.567$	0.980	186	40.03
S3	$y = -0.0004x^2 + 0.416x - 20.954$	0.994	175	37.96
S4	$y = 0.0003x^2 + 0.4102x - 23.577$	0.986	175	40.52
S5	$y = -0.0008x^2 + 0.5289x - 32.383$	0.994	181	37.14
S6	$y = -0.0005\ x^2 + 0.4425x - 27.719$	0.987	176	40.28
Mean			180	40.26

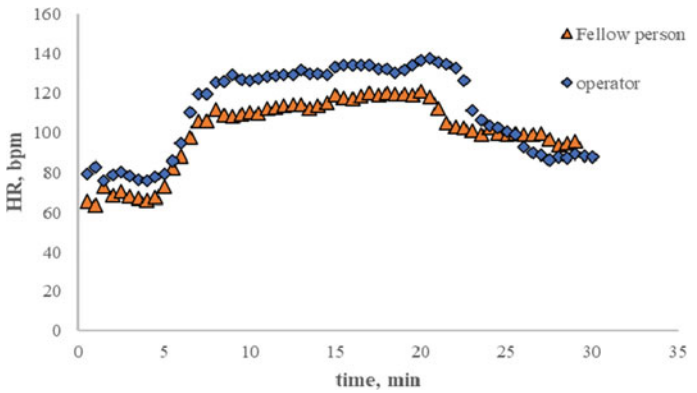

Fig. 5 A sample curve of HR with time recorded during puddling operation

3.2 Field Data

The sample curve of heart rate versus time for power tiller operator and fellow person during puddling and tilling operations are shown in Figs. 5 and 6, respectively. This gives a clear indication that the working heart rate of the operator is higher than fellow person in puddling as well as in tilling operations. The measured HR during puddling and tilling operations for the power tiller operator and the fellow person is shown in Table 3. The calculated value of the volume of oxygen consumption (VO_2) and corresponding EER is also given in table. It was observed that the average HR, VO_2 and EER of the operators during puddling were 10.08, 23.10, and 10.91% higher than tilling. Further, the average HR of fellow person was 11.26 and 13.15% lower than operator during puddling and tilling, respectively. The percentage of VO_{2max} consumed by the operator during puddling and tilling were 72.66 and 58.34%, respectively which is considered as very high. The average human energy required for walking behind the power tiller during puddling and tilling operation are 3048 and 1784 kcal/ha, respectively. However human energy for fellow person for puddling and tilling are 10 and 22% lesser than power tiller operators.

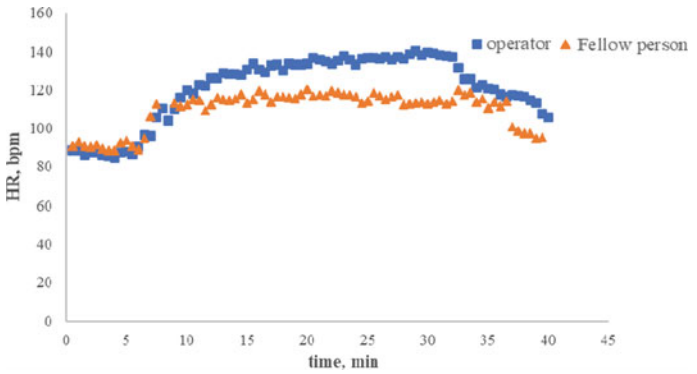

Fig. 6 A sample curve of HR versus time recorded during tilling operation

Table 3 Calculation of EER during puddling and tilling

Operation		Measured value			Calculated value			
		AFC, ha/h	HR rest, bpm	HR work, bpm	VO_2, ml/min/kg	EER, kcal/min	Human energy, kcal/ha	% of VO_{2max}
Puddling	Operator (6)	0.098	79	142	29.20	4.98	3048	72.66
	Fellow person (3)		63	126	22.29	4.49	2748	67.56
Tilling	Operator (4)	0.117	76	129	23.72	3.48	1784	58.34
	Fellow person (4)		74	114	18.64	2.74	1405	53.27

4 Conclusions

The following major conclusion was drawn from the study:

i. The heart rate and energy consumption during puddling operation were higher than tilling operation.
ii. The heart rate of the fellow person was lower than the operator in both the operation because of associated vibration and noise level.
iii. Walking behind the power is considered as very heavy work as the required maximum oxygen is more than 50% of VO_{2max}.

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Quantification of Neurosignals for Mathematical Model Development of Muscle Fatigue from Inexperienced Worker

Rohit Kumar, Ankit Kumar, Rajesh Kumar, and Parveen Kalra

Abstract Work Related Musculoskeletal disorders (WMSDs) are the occupational diseases that cause inflammation and degeneration of muscles, bones, tendons or ligaments. WMSDs pose huge challenges to the manual workers and labor oriented industry. This article is primarily focused upon providing relevant results that can eventually be used for the development of mathematical model of the muscle fatigue using Neurosignals. A 32 year old inexperienced worker weighing 65 kg and 5 ft. 8 in. tall chosen for this study and electromyography (EMG) signals of his muscles were analyzed for an entire working day (7 h) for 6 consecutive days. The EMG data was collected from four of the most affected muscles in the industry which were Flexor Digitorum, Extensor Digitorum, Bicep Brachii and Deltoideus Scapularis respectively. The RAW EMG data was further converted into median frequency (MDF) values using suitable filter. Results obtained compared between different muscles and validates previous studies. The observed data evidently shows direct relation between the slopes of MDF lines and successive days. Output of the study can be further used for muscle fatigue quantification and mathematical model development.

Keywords Musculoskeletal disorders · Electromyography · Neurosignals · Muscle fatigue · Median frequency

1 Introduction

Work related musculoskeletal disorders (WMSDs) are common in the workplaces and affects large number of industrial workers throughout different industries [1]. WMSDs are responsible for nearly one-third of all the occupational diseases that are registered in the United States and two-third of the occupational diseases in France [2]. Cumulative trauma disorders (CTD) are responsible for more than 50% of all the occupational diseases in the United States. These are the disorders that arise due repetitive motion or activities [1]. These WMSDs are of serious concern

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to the workers, their families and the organizations they work for as their bad health adversely affects the livelihood of their families and industrial output of the related organizations. WMSDs are also a major cause of financial draining for these organizations which could also be in the form of compensations given to the effected workers or in the form of reduced output [3]. The number of workers receiving disability pension for such disorders has increased steadily over the last few decades in many of the European countries like Norway and U.K. The probability of taking these disability pensions increased with increase in age [4].

WMSDs can simply be defined as wide range of inflammatory, degenerative conditions or injury of muscles, tendons, peripheral nerves, back or lower and upper extremities [1, 2, 5]. In most of the cases these disorders are accompanied by symptoms like numbness, pain, soreness or aching in the effected body parts [1]. The biggest causes of these disorders are repetitive motion, lifting of heavy loads, pushing, pulling and awkward postures [1, 4]. In the manual industry, the most severely affected body parts are the upper limbs like forearm, shoulder, neck and even low back [1, 2]. The upper limb disorders are mostly encountered in occupations like cleaning, packaging and inspection industry where as lower limb disorders are more prevalent in house or construction workers, truck drivers and baggage handlers [2, 3, 6]. This disorder depends on working condition and several other factors like environmental and type of work handling. In this article fatigue of most affected four muscles in manual work were taken in to consideration.

2 Muscles Fatigue

Muscle fatigue is characterized by failure of muscle to maintain the anticipated level of force and arises due to reduction in muscle function [1, 7]. It is also termed as subjective lack of mental or physical energy [7]. It mainly depends upon the type of contraction, intensity and also the duration for which the activity is performed. Fatigue may be local or systematic fatigue and both of these are related to different kind of physical activities. Local fatigue generally happens due to long working periods or by bad posture while working. Systematic fatigue happens due to manual work and mental reasons [1]. This work incorporated both fatigue for an inexperienced worker that includes central and peripheral fatigue at neuromuscular junction.

2.1 Measuring Muscle Fatigue

Muscle fatigue can be measured through subjective scales, accelerometers, biomechanical analysis, by measuring physiological signals or rate of oxygen consumption may also be used [8, 9]. Questionnaires are frequently used for the assessment of exposure due to their low cost [9].

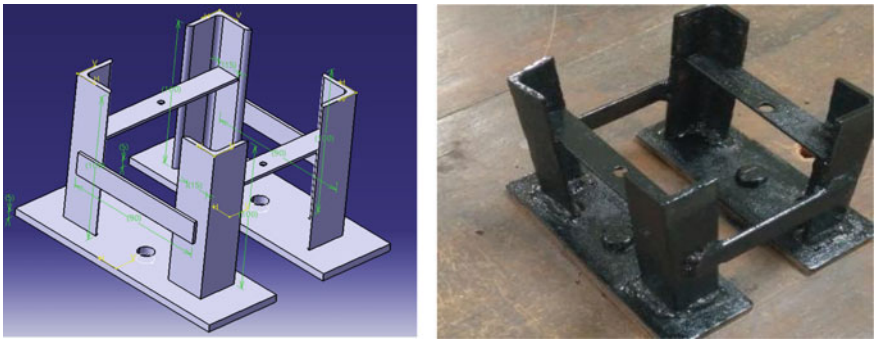
Electromyography (EMG) is a graphical method used to observe the muscle activity in the form of signals [10]. Recently, many applications, including engineering and medical, based on the analysis of EMG signals have been developed [11, 12]. EMG analysis is regularly used in the study of biomechanics and in the research of movement control to study the role of nervous system in the production of motion using muscular contraction [12]. It is a direct method of measuring the muscle fatigue. Surface electromyography is a non-invasive technique for recording the muscle activity from above the surface of the muscle. Features that are time-domain or frequency domain are the important ones. Mean absolute value and zero crossing per second are the most commonly used features in time domain analysis. The features that are used for the detection of muscle force are generally time-domain, but these features are found to be ineffective for detecting the muscle fatigue [13]. On the other side, the frequency domain features are known for their accuracy in measurement of muscle fatigue. A simple and frequently examined feature in frequency domain is median frequency (MDF) [8]. While looking for the EMG signals the two main parameters that may vary the fidelity of signal are signal to noise ratio that is simply the ratio of energy of EMG signal to that of noise signal [10]. MDF basically divides the EMG power spectrum into two regions by equal power. Most of the researches related to quantification of the muscle fatigue make use of median frequency as it is the most representative parameter. There is a theory that increase in muscle fatigue leads to shift of frequency spectrum of the signal [13].

3 Signal Acquisitions

A 32 year old inexperienced male worker, weighing 65 kg and 5′8″ tall, was randomly selected for the plate assembly experimental analysis. Before beginning with the experimental work, a consent form including the title and the objective of the experiment, estimated duration of tasks, possible risks related with the work and benefits of the study was conveyed to the worker for his consent. Worker's BMI was also checked and was found to be in healthy range. Prior to the task it was made sure that worker was physically fit and had not performed any heavy lifting or other high intensity activity. A BIOMETRICS Ltd. DATALOG (Type No. MWX8) was used to record EMG signals of the subject. EMG surface electrodes, active probe SX230, were stuck onto the skin of the worker to gather the neurosignals and software from BIOMETRICS Ltd. was used to collect and measure the EMG signals of the muscles under observation.

4 Experimental Procedure

The readings were taken by using a 0° fixture used in industry for manual work is, shown in Fig. 1 that was specifically designed after thoroughly studying different



(a) (b)

Fig. 1 Working fixture at 0° shoulder abduction. **a** CAD image file, **b** actual fixture

(a) (b)

Fig. 2 EMG signal acquisition from muscles **a** Deltoid, **b** Extensor Digitorum

shoulder abduction angles. Allen key and three different types of nuts and bolts of M10 size were used for joining the fixture plates. In order to challenge the worker mentally the fixture plates had holes in specific positions so that the two plates would join only if the holes on both the plates were matched. Before the readings were taken the worker was made aware of the task and related risks. Studies mandates effect on shoulder, Biceps and Forearm and muscles associated with these areas are more prone to muscle fatigue.

Therefore, 4 muscles were selected for present studies. These muscles are shown in Fig. 2. One of assembled plates with different bolt heads is shown in Fig. 3. Assembly starts with few manual turns with free hand followed by tightening with key so that inexperienced work may feel some fatigue in his respective muscles. EMG sensors stuck onto the skin of the worker after it is thoroughly cleansed. All the tools and the fixture plates were kept within in the working range of the worker

Fig. 3 Final assembly of plates

and the Allen key used in the experiment was kept on the side of the dominant arm. As the number of fixture plates was limited therefore, another worker was employed to disassemble the joined plates in order to maintain the continuity. The EMG readings were recorded first at 11 a.m. in morning and successive readings were taken after every single hour. A lunch break was given at 1 p.m. for an hour and the readings were again continued afterwards at a gap of every hour and last readings were taken at 4 p.m. in the evening. Hence, 6 readings were taken in a single day for 6 consecutive days every hour starting from 11 a.m. to 4 p.m. The host software was used to setup the channel. For the active probe SX230 the channel sensitivity was set at 1 mV dc with the sampling rate of 1000. The excitation output was set to 4600 mV while the full scale was set at 3 mV.

5 Results

There are two main available techniques for quantification of neurosignals called Linear and Non-linear. In linear techniques Mean/Median/Total Power frequencies may be used for quantification. Here, in the present model Median Frequency (MDF) is used for quantification. Relation between median frequency and time is shown and slopes of the fit curves for all the six days are compared and studied.

Decrease in MDF over the number of working hours indicated towards the appearance of muscle fatigue. Slope of the MDF line increased gradually from day 1 to day 6 which showed that the rate of occurrence of muscle fatigue also increased gradually from day 1 to day 6. Low variation in slopes shows behavior of motor retention skill of muscles and gradual increase shows jump in muscle fatigue. This behavior can been seen earlier in very first day in case of Extensor Digitorum muscle, however for other muscle like flexor Digitorum it can be seen on third day.

These variations depicts different set of muscles have different degree of variation in muscle fatigue activity. As, MDF decreased with increase in number of working hours it can be said that level of fatigue was also rising during the same time on same day. Data of 6 days acquired for all muscles, one of which shown in Table 1. Smaller

Table 1 MDF value of Flexor Digitorum over course of 6 days

Reading	Day 1 (Hz)	Day 2 (Hz)	Day 3 (Hz)	Day 4 (Hz)	Day 5 (Hz)	Day 6 (Hz)
1	86.18	91.37	100.12	93.68	87.28	94.75
2	86.9	85.43	81.06	80.25	80.5	81.12
3	65.06	66.5	89.93	78.37	69.68	76.8
4	72.62	74.56	91.93	86.41	73.21	78.06
5	68.93	78.93	79.5	71.83	67.4	74.5
6	72.06	70	88.68	67.52	62.15	65.56

slope indicates towards slower decrease in MDF which further points that the rate of occurrence for the respective muscle is very slow, as in case of Extensor Digitorum. Especially in case of Extensor Digitorum it is observed that it does not show change in fatigue level over successive number of days although its rate of fatigue for a given day could be high.

The observations made also show that the results may vary for linear and polynomial fits. So it matter of further study to find the right curve that fit into these readings and give better results. Based on the data acquired above studies on the intra-day variation in the MDF of the muscles has been done with the help of statistical parameter coefficient of variance C.O.V. (Standard deviation, σ/mean, μ), and day wise values of these COV's have been used to see the trend of its variation over a period of six continuous days with the help of best mathematical curve fitting as shown in Figs. 4 and 5.

6 Discussion

The MDF readings were first used to draw the scatter plots and then these plots were fitted with straight lines in order to find the linear relation between MDF and time to observe its behavior over the period of six consecutive days. The graphs showed that the MDF of all the muscles under observation decreased over the course of a single day. It was also observed that the slope of the fit lines that depicted the MDF values increased gradually from the first day of the task to the last day of the task. Hence it can be concluded that the rate of decrease of MDF increased with increase in the number of working days for all the four muscles. It was further observed that the rate of occurrence of muscle fatigue increased with increase in rate of decrease of MDF over the period six consecutive days. According to the results, most of the work was performed by Flexor and Extensor Digitorum whereas Biceps Brachii and Deltoideus Scapularis played less significant role. The rate of decrease of MDF was also observed to be higher for Flexor and Extensor Digitorum which indicated the both of these muscles fatigued at much faster rate as compared to other two muscles.

In this study the data was obtained for six consecutive days while keeping all the working conditions of an average industrial worker around the world in mind. A

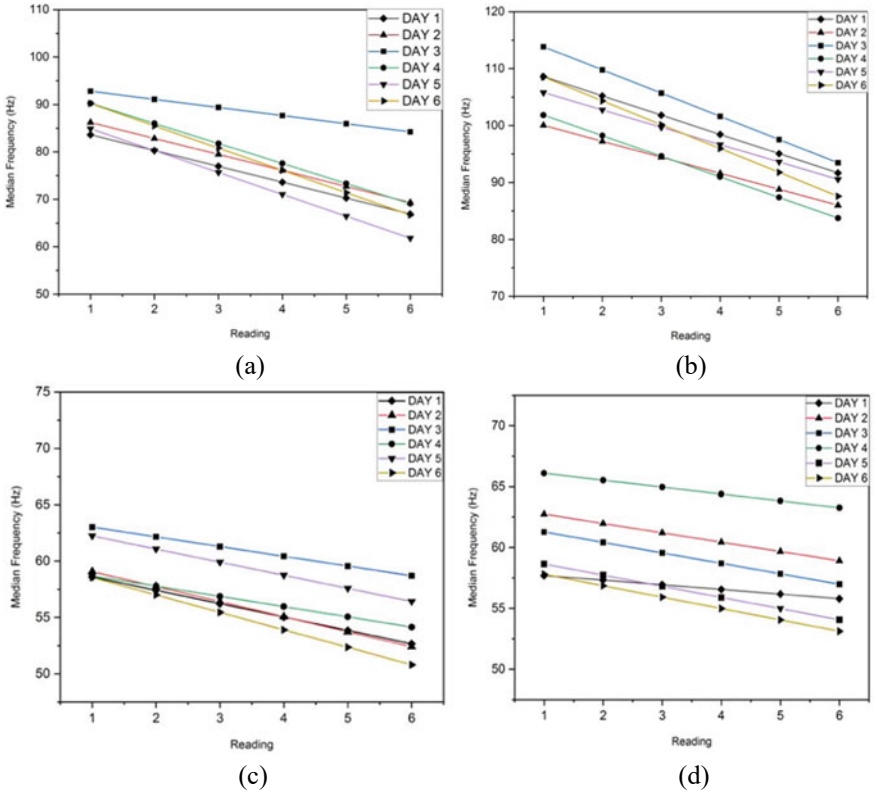


Fig. 4 Variation in MDF over 6 days for **a** Flexor Digitorum, **b** Extensor Digitorum, **c** Bicep Brachii, **d** Deltoideus Scapularis

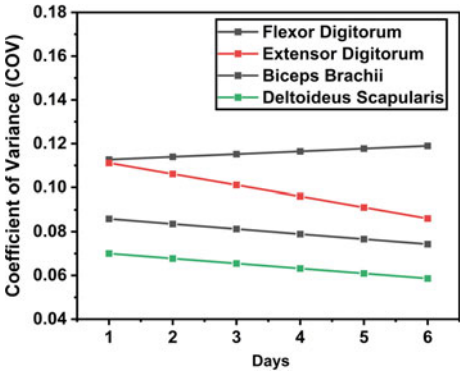


Fig. 5 Variation of COV over 6 days of different muscles

lunch break and designated rest break were also given so that the working schedule to resonate with the actual work timings in the industry as much as possible. It is a known fact that MDF of a muscle decreases over the period of time but in this study it was also found that the rate of decrease of MDF increased over the successive days, although the decrease in slopes of the lines was gradual. These observations clearly indicate increase in level of muscle fatigue and decrease in rate with which a muscle repairs. Hence this decrement in the rate of muscle repair eventually deteriorates the condition of the muscle and lead to MSDs. As the se slope of the fitted lines decrease gradually, these trends can be used to generate a mathematical model to estimate the level of fatigue of the worker by extrapolating the obtained set of data. The model developed with the use of these observations may help to avoid enhanced levels of muscle fatigue which eventually lead to MSDs. The main purpose of this study was to analyze the relationship between the muscle fatigue and the continuous work flow of an industrial worker. The findings of this study can be wisely used to avoid such disorders among the workers by designing a better work environment which is not only related to the physical aspects of the workers body but also makes a better psychological impact.

7 Conclusion

The findings of the study show a strong correlation between the number of working hours and muscular tiredness in the most afflicted body part during manual handling of low load and high frequency work in an inexperienced worker. The rate of decrease of MDF for all four muscles decreases at a faster rate with increase in number of days worked. Inter-day muscular fatigue also confirms same findings however, the degree of fatigue varies.

Fixing limiting value of the MDF based on COV at which the MSD would set in and the time after which an industrial worker will acquire such limits is the starting step to develop mathematical model based on extrapolation after taking into consideration rest periods for muscle recovery and other activities of the Industrial worker.

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Analysis and Improvement of Working Postures in Cargo Securing Process During Outbound Shipment by Using Different Ergonomics Tools and Software

Rahul Pradeep Bhosale and M. Sunil Kumar

Abstract The main objectives of this study were to identify the most problematic postures in hammering tasks performed at outbound shipment process within logistics through application of the computerized Classic Jack Software and Ergonomics analysis tools such as Rapid Entire Body Assessment (REBA), Safety and Ergonomics Risk Assessment (SERA) and Rapid Upper Limb Assessment (RULA) method, and to develop recommendations for improvement of working methods and workplaces. The manufacturer exports the product through sea containers, and it is very important to secure the product inside the container by nailing and lashing operation so that product will not get damaged during transportation. The lashing and nailing operations are required to secure product inside the container and both are below the knee level operations which are ergonomically not safe. The outbound shipment process ergonomics and productivity is improved by eliminating hammering operation and inefficiencies in the container loading and unloading process through designing the unique self-locking pallet which doesn't need any securing operation like nailing and lashing. The "Lean and Triz" are employed to solve problems and improvements were recorded. The container loading time is reduced from 53.4 to 28.4 min for palletizing shipments hence productivity improved by 46.81%. SERA score reduced from 48 to 1. REBA score reduced from 11 to 3. RULA score reduced from 7 to 2. The overall increase in the productivity of outbound shipment by ~47% and reduction in the ergonomics risk to bare minimum.

Keywords Logistics · Ergonomics · REBA · SERA · RULA · Productivity

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1 Introduction

Ergonomics is science of fitting workplace to user's need, comfort, aim to improve productivity and to reduce ergonomics risk [6]. Ergonomics can play an important role in supporting material management in industrial world. Ergonomics allows an employee to work at their highest level of productivity, efficiency and safety. Musculoskeletal disorders are a major problem for an industry. Hand tool-related injuries bring to light that hammers and hammering operation performed in discomfort postures were important contributory factors to musculoskeletal disorders [5].

The manufacturer export different agriculture machines across the globe. The improvement in logistics needs to meet current and future demand of customer on time. The use of shipping containers is more common for export across the globe. If logistics fails to dispatch shipment on time to destination country, then there will be delay of one week as freight forwarder frequency is once per week to different country, hence dispatching the cargo on time from logistics dock is challenging task for company and need improvement. The economics of handling cargo is very important for a company as improvement in cargo handling can directly add profit to company.

In logistics the container loading requires manual material handling. Once the cargo is loaded into the container it should be secured properly. Operator performs nailing and lashing operation to secure the cargo inside the container (refer Fig. 1). Lashing is the process of constraining the consignment while in transportation to ensure damage free shipment. Lashing operation required pulling of nylon belts at ground level with excessive motion and high pull force (refer Fig. 3). A nailing is an operation in which wooden blocks and metal nails are used to constrain the machine motion in all direction so that it will not move while in transportation (refer Fig. 2). The nailing operation is completely below the knee level and contributing to work-related muscular skeletal disorders (WMSD).

Fig. 1 Product secured using wooden block and nails

Fig. 2 Operator performing nailing operation

Fig. 3 Operator performing lashing operation

This paper focuses on evaluation of Ergonomics risk associate with nailing and lashing operation by using different Ergonomics risk analysis tools and provide a solution to eliminate the Ergonomics risk and to increase the productivity.

2 Literature Review

Ijaz et al. conducted quantitative and qualitative assessment of musculoskeletal disorders and socioeconomic issues of workers of brick industry in Pakistan. During the study it was found relation between 5 work stages and Work-related muscular-skeletal disorders in 9 body parts and finds socioeconomic sufferings impacted by the industry. The experiment was conducted which include 105 men and 45 women from 15 brick factory were selected as subject. Different ergonomics assessment tools such as Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA), Standard Nordic MSDs Questionnaire, Work photography and video recording were used

to carry out the assessment. The mean worker height found to be 1.67 m and mean body weight was found to be 58 kg.

Digging and carrying jobs caused considerable pain in body parts including neck, upper back, shoulders, lower back and hips. The Rapid Upper Limb Assessment (RULA) score for mixing and molding operation was 7 and it was most risky activities for most of the body parts which causes an injury. For the same activity the Rapid Entire Body Assessment (REBA) was 9 and 13 respectively [3].

Côté et al. studied the effect of repetitive hammering on individuals which causes work-related muscular skeletal disorders (WMSD). The study showed that fatigue impacted the elbow motion while shoulder injury impacted both wrist and elbow motions during hammering operation. Work-related muscular-skeletal disorders have been previously related to movement repetition, awkward postures, on-ergonomics environments, muscular unsymmetrical balance and fatigue. However, no direct relationship between fatigue and injury has been shown. To address this issue the impact of fatigue and injury on the kinematics of repetitive hammering operation were compared. The field study was conducted on 30 healthy workers performing repetitively hammering operation both before and after fatigue. Fatigue was increased by a both static and dynamic motion. In next slot the study was conducted on 15 operator who has shoulder-injured and performing hammering operation for 30 s without fatigue and kinematics of motion was recorded. Results showed that fatigue impacted elbow movement at the same time shoulder injury impacted both wrist and elbow movement during repetitive hammering operation. However, shoulder kinematics were not altered by either fatigue or shoulder injury. These modification at the wrist and elbow may result in strategies used by individuals with shoulder injury to maintain same motion duration and shoulder kinematics during operation [1].

Mattila et al. analyzed the working posture in hammering tasks on building construction sites. The study showed that hammering tasks often involve the poor working postures [5]. The main goal of this study was to identify the awkward postures in hammering tasks executed at construction sites through application of the computerized Ovako Working Posture Analysis System (OWAS) method, and to develop suggestions for improvement of work postures and operation methods and workplaces. Total 593 different postures were analyzed, out of which 7.8% of postures adopted by the workers were classified into Ovako Working Posture Analysis System (OWAS) categories III or IV, indicating that these postures have high risk of work-related muscular skeletal disorders and should be corrected or improved either soon or immediately. The category III or IV means work postures with an extremely harmful effect on the musculoskeletal system [4].

3 Problem Definition

There were some complaints from operator regarding back pain, palm pain and some near miss happened during nailing operation which was reported due to lashing and

nailing operation while loading and unloading cargo. The detail study of current cargo loading highlighted some issue as below,

- Frequent Bending operation (10 times per container)—**Back Pain**,
- Tight Grip of Hammer and Impact force—**Palm Strain and Pain**,
- Repetitive Hammering operation (75 strikes per container)—**Knee Pain and Fatigue—Too Much**,
- Below the knee level operation—**Too Low**,
- High belts pull force (>15 kg)—**Too Much**,
- Frequent interaction of Operator and forklift—**Unsafe Environment**,
- Low Illumination inside container—**Visibility Concern**.

The objective of the current study is as below,

- To study ergonomics risk associated with container loading and unloading by using different ergonomics analysis tools such as SERA, RULA and REBA.
- To reduce ergonomics risk and increase operator efficiency and morale.

4 Methodology

The methodology used for this work is shown in flowchart Fig. 4. The analysis of the existing cargo loading processes was carried out by ergonomics assessment tools. This methodology consists of five stages: (1) Diagnosis—Pre-Ergo analysis; (2) Planning Action—Solution; (3) Implementation of solution; (4) Evaluation—Post-Ergo analysis; (5) Result and conclusion.

In logistics the container loading requires manual material handling. Once the cargo is loaded into the container it should be secured properly. Operator performs nailing and lashing operation to secure the cargo inside the container. The nailing operation is completely below the knee level and contributing to work-related

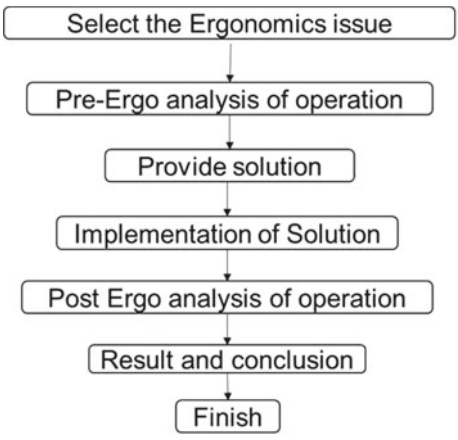

Fig. 4 Methodology flow chart

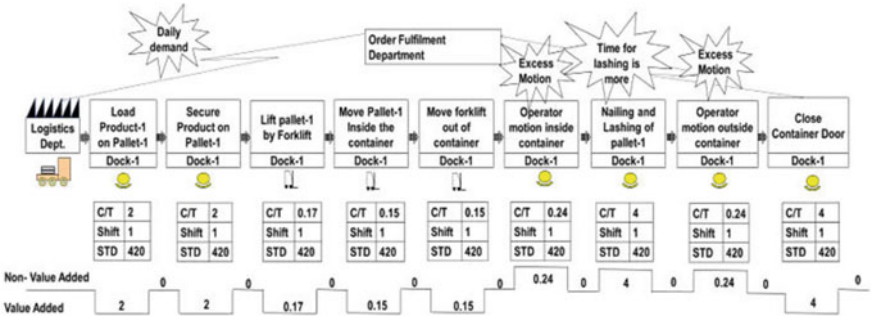

Fig. 5 Value Stream Mapping of Pallet loading process inside the container

muscular skeletal disorders (WMSD). Manual material handling is the most common cause of musculoskeletal disorders (MSDs) and increasing ergonomics risk which involves manual lifting of heavy weights, carrying, pushing, and pulling loads [2].

The first step is to understand and capture the current process flow for palletizing loading. One 40 ft. container can accommodate 5—pallets inside the container. Operator performs the nailing and lashing operation to secure the cargo inside the container. The process flow for one pallet loading is shown in Fig. 5. The same process is repeated 5 times per container to load 5 pallets inside the container.

4.1 Pre-ergonomics Analysis

There is need of ergonomics assessment and resolve the ergonomics issue on priority due to mentioned ergonomics issue in problem section. Hence different Ergonomics evaluation tools and software is used to analyze the ergonomics issue.

4.1.1 SERA Analysis—Safety and Ergonomics Risk Assessment (SERA)

SERA is a tool to evaluate risk to established criteria to quantify a Risk Priority Number (RPN). The SERA tool and process helps in quantifying, prioritizing and communicating projects or risk. Table 1 shows the standard value SERA (Safety and Ergonomics Risk Assessment) criteria and Score.

The Risk Priority Number (RPN) was calculated by multiplying the ranking obtained from Severity, Exposure and Vulnerability. The severity is defined as the seriousness of injury ranging from least serious to most serious depends on muscle fatigue to fatality respectively and ranking changed from 1 to 6 respectively. The exposure is defined as how often the operator is exposed to hazard during the complete cycle of operation out of 100%. The frequency varies from least frequent (1–10% of

Table 1 Standard value SERA (Safety and Ergonomics Risk Assessment) criteria and score

	Severity	
Frequency	Criteria: seriousness of injury	Ranking
Most serious	Fatality	6
	Lost time-missed work due to injury	5
	Recordable injury with surgery	4
	Recordable injury	3
	First aid	2
Least serious	Muscle fatigue/discomfort	1
	Exposure	
Frequency	Criteria: how often the operator is exposed to hazard	Ranking
Most frequent	75–100% of cycle	6
	75% of cycle	5
	50% of cycle	4
	Less than 30% of cycle	3
	Less than 20% of cycle	2
Least frequent	1–10% of cycle	1
	Vulnerability	
Frequency	Criteria: likelihood that an incident will occur	Ranking
Most likely	Certain	6
	Frequent	5
	Probable	4
	Occasional	3
	Remote	2
Least likely	1–10% of cycle	1

the cycle) to most frequent (75–100% of the cycle) and ranking changed from 1 to 6 respectively. The Vulnerability is defined as likelihood that an incident will occur. The frequency varies from least likely (1–10% of the cycle) to most likely (Certain) and ranking changed from 1 to 6 respectively.

$$\textbf{Risk Priority Number (RPN)} = \textbf{Severity} \times \textbf{Exposure} \times \textbf{Vulnerability}$$

Table 2 shows the Pre-SERA score for nailing and lashing operation. The Pre-SERA score is = 48. The SERA score is very high and need immediate attention to issue.

Table 2 Pre-SERA (Safety and Ergonomics Risk Assessment) score for nailing and lashing operation

Pre-SERA score		
	Severity	
Frequency	Criteria: seriousness of injury	Ranking
	Recordable injury with surgery	4
	Exposure	
Frequency	Criteria: how often the operator is exposed to hazard	Ranking
	Less than 30% of cycle	3
	Vulnerability	
Frequency	Criteria: likelihood that an incident will occur	Ranking
	Probable	4
	Total Risk Priority Number (RPN) score	48

4.1.2 Rapid Entire Body Assessment (REBA) Analysis

Rapid Entire Body Assessment (REBA) is an ergonomics assessment tool used for a systematic analysis of whole-body postural MSD's (Musculoskeletal Disorders) and ergonomics risks associated with job tasks (6).

A maximum allowable pulling force for male worker is 26 kg and for female worker is 19 kg (3). The force required to pull the ratchet belt is more than 30 kg which causes pain in arm and shoulder.

The REBA (Rapid Entire Body Assessment) analyzes and evaluate selected body posture, forceful exertions, type of movement or action, repetition, and coupling. The REBA (Rapid Entire Body Assessment) grand score is 11 which indicates the very high-risk level with investigation and action required immediately on priority. Figure 6 shows the pre-REBA analysis rating and grand total REBA score.

From Fig. 6 it is clear that twisting in trunk is more than 30° hence score is 3, twisting in neck is more than 20° hence score is 2, bending in leg in more than 60° hence score is 4, shoulder position is more than 45° hence score is 2, wrist rotate more than 20° in nailing operation hence score is 2. The total grand score is 11, which indicates the immediate attention and resolution is required.

4.1.3 Rapid Upper Limb Assessment (RULA) Analysis

The Rapid Upper Limb Assessment (RULA) analysis is conducted using classic jack software to check accuracy. Classic jack is an ergonomic assessment software in which human can be modeled and operation can be simulated. The virtual environment is created in jack to simulate the actual nailing and lashing operation. The container, pallet and human are inserted in the software. Input parameter are provided (such as no of cycle, pull force, no of pull per cycle, no of hammering per pallet etc.)

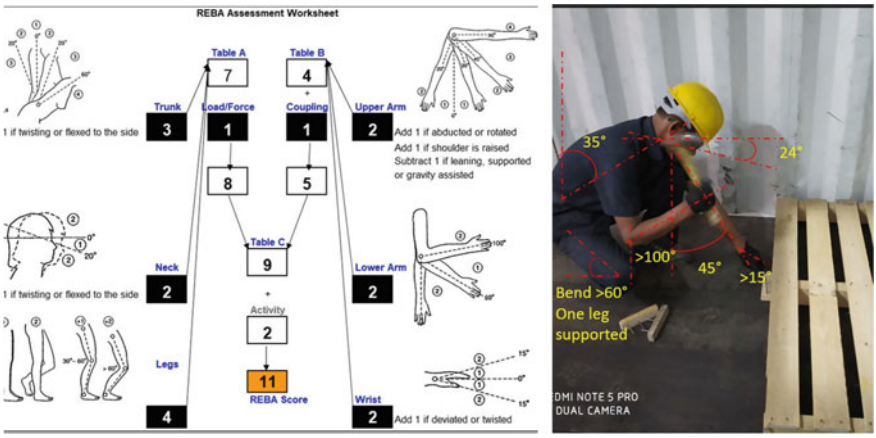

Fig. 6 Pre-REBA (Rapid Entire Body Assessment) analysis

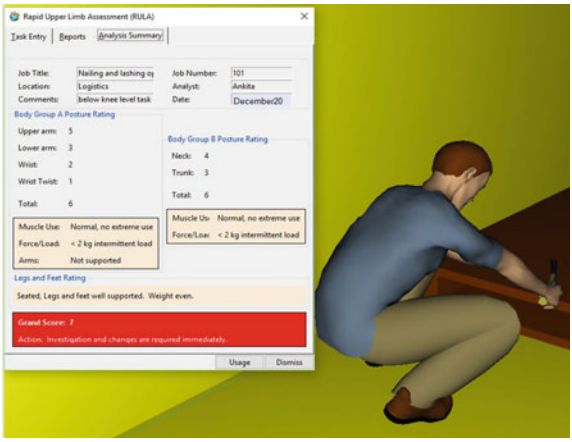

Fig. 7 Classic jack RULA pre-assessment

and actual operation is simulated, and result is captured. Refer Fig. 7 for classic jack RULA assessment using software.

The total grand score is 7, which indicates the immediate investigation and changes are required.

4.2 Solution

The initial thought towards the solution was selecting the off the shelf solution available in the market which is proven one. There are different patented solutions available for locking the cargo but those were very complex and costly. One of

the solutions required manual locking and unlocking, hence those solutions were rejected.

There was a need to develop the frugal, low-cost and sustainable solution which will focus on, **less operator motion, less fatigue, ergonomically safe, lower cycle time, easy to load and unload and sustainable solution**.

The new pallet design is self-interlocking design in which two pallets interlock with each other to arrest all degrees of freedom. It does not need any lashing and nailing operation. The flat hollow bent pipe on pallet-2 interlocks with the vertical hollow bent pipe on pallet-1. Pallet-1 and pallet-2 butt against each other. The butting and interlocking prevent the 12 degrees of freedom and secures the cargo inside the container without nailing and lashing. Also note that the pallet width is 2300 mm and the container inside width is 2340 mm. Figure 8 shows the self-interlocking pallet solution.

This solution was implemented and operator feedback was taken regarding the ease of this solution. The solution was acceptable on SQDPC matrix. The SQDPC matrix is fully satisfied now. Refer Table 3 for SQDPC matrix evaluation after implementation of self-interlocking pallet solution.

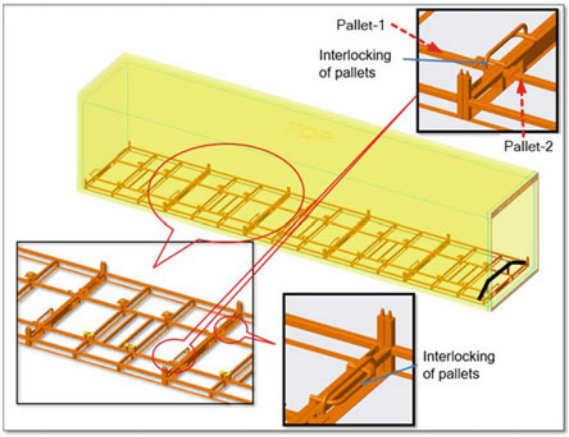

Fig. 8 Self-interlocking pallet solution

Table 3 SQDPC matrix evaluation for self-interlocking pallet solution

Self-interlocking pallet design solution	
Matrix	Remark
Safety	Yes—Safer operation. No interference of forklift and operator
Quality	Yes—Ensuring no product damages
Delivery	Yes—Loading and unloading time is very less
Productivity	Yes—Loading and unloading time is very less
Cost	Yes—Packaging and operation cost got reduced

From Table 3 it is clear that there is an improvement in safety, quality and productivity, cost is reduced drastically hence this solution is fully accepted. The forklift and operator interface are eliminated completely due to no operator movement inside the container and hence safety increased. Due to securing the product on pallet properly it ensures the quality of product will remain the same and there will be no damages to the consignment during the transit. The productivity of loading and unloading the container is increased as nailing and lashing operation is eliminated. The cost required for loading and unloading of container is reduced and packaging cost required for ratchet belt also got eliminated. Hence this solution satisfies all the criteria of SQDPC matrix and fully accepted for implementation.

4.3 Post-ergonomics Analysis

4.3.1 SERA Analysis—Safety and Ergonomics Risk Assessment (SERA)

The nailing and lashing operation are eliminated, which causes major fatigue to the operator. The severity level got reduced to muscle fatigue with ranking 1, the exposure to hazard got reduced from 30% of cycle time to 1–10% of cycle time hence ranking reduced to 1, operator motion inside the container is also eliminated that will decrease the chances of accident hence ranking reduced to 1 ($1 \times 1 \times 1 = 1$).

$$\textbf{Risk Priority Number (RPN)} = \textbf{Severity} \times \textbf{Exposure} \times \textbf{Vulnerability}$$

$$\textbf{Risk Priority Number (RPN)} = \mathbf{1} \times \mathbf{1} \times \mathbf{1} = \mathbf{1}$$

The grand total Safety and Ergonomics Risk Assessment (SERA) score is 1. Safety and Ergonomics Risk Assessment (SERA) score reduced from 48 to 1.

4.3.2 Rapid Entire Body Assessment (REBA) Analysis

As the nailing operation is eliminated the REBA (Rapid Entire Body Assessment) score reduced drastically from 11 to 3. Figure 9 shows the post-REBA analysis rating and grand total REBA score.

From Fig. 9 there is no twisting in trunk hence score is 1, twisting in neck is up to 20° hence score is 1, bending in leg is less than 60° hence score is 1, shoulder position is less than 45° hence score is 1, wrist rotate less than 60° in nailing operation hence score is 1. The total grand score is 3.

REBA score reduced from 11 to 3. The nailing and lashing operation include frequent bending which causes back pain, tight grip of hammer and high impact

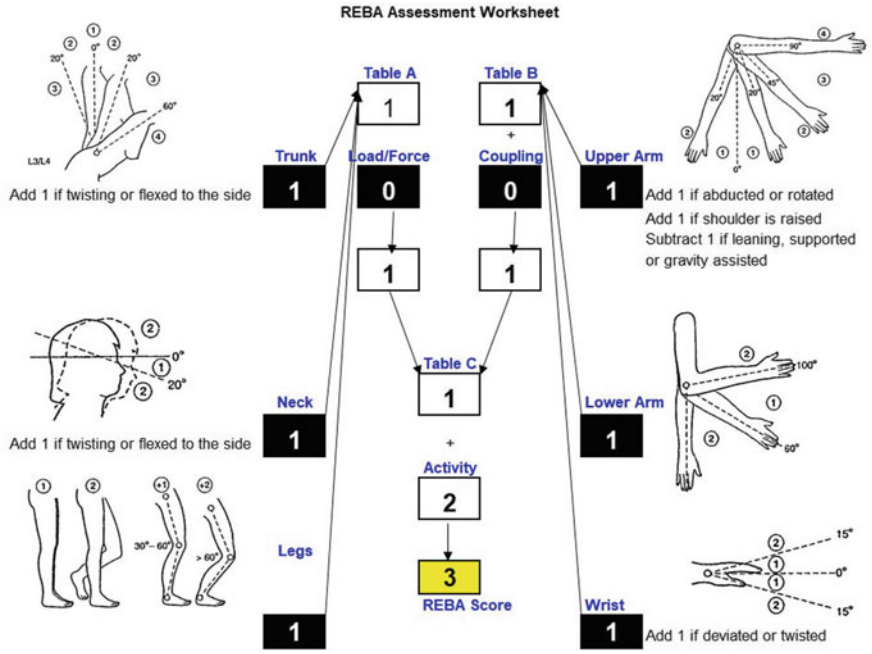

Fig. 9 Post-REBA (Rapid Entire Body Assessment) analysis

force which causes palm strain and pain, the repetitive operation which causes knee pain and fatigue hence the REBA score is more. After the change in packaging the REBA has been reduced to a safe and acceptable level. Morale of operator gone up as ergonomics issue got resolved.

4.3.3 Rapid Upper Limb Assessment (RULA) Analysis

The nailing and lashing operations are eliminated and hence there is no operator interaction during cargo loading and unloading process. Hence the grand total RULA score is 1. Refer Fig. 10 for post RULA assessment using classic jack software.

5 Discussion

The nailing and lashing activities are performed at ground level by an operator in awkward positions and causes a discomfort. The SERA score reduced from 48 to 1. The REBA score reduced drastically from 11 to 3. The similar kind of ergonomics assessment done by Ijaz et al. for workers working in the brick industry in Pakistan. There is similarity between the brick manufacturing process and nailing or lashing

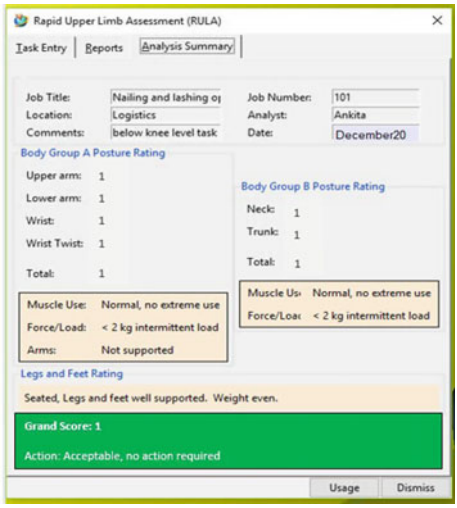

Fig. 10 Classic jack RULA post-assessment

operation as both are carried out at ground level and causes discomfort to operator. During assessment Ijaz et al. found that the REBA score was 13 for molding and framing activity which is very high, causing discomfort on legs and lower back which need to resolve on priority [3].

Deros et al. did a study on ergonomics awareness among the workers performing manual material handling activity which involves manual lifting, lowering, carrying, pushing and pulling loads. RULA assessment was conducted to find out, ergonomics risk of manual material handling activity. The RULA score was 7 and risk level was 4 which indicates a high risk on arms and wrist. For manual handling REBA and RULA score varies from 13 to7 which is high and need improvement and action on priority [2]. In comparison with reference study for loading and unloading to container the REBA score is 11 which is close to the manual material handling activity.

6 Conclusion

- The nailing and lashing operations are eliminated with zero ergonomics risk.
- The Safety and Ergonomics Risk Assessment score reduced from 48 to 1.
- The Rapid Entire Body Assessment score reduced drastically from 11 to 3.
- Rapid Upper Limb Assessment score reduced from 7 to 1.
- The palletizing shipment container loading time was reduced from 53.4 to 28.4 min per container loading. The total annual time saving is 492 h for 1200 containers and productivity is improved by 46.81%.

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An Improved User Interface for Enabling Smart Access Using Low-Cost QR Based Systems

Shaivi Kant and Sai Prasad Ojha

Abstract Organizations of today are scrutinized for neglecting safety and healthcare of their employees The entry/exit points witness rigorous human contact and are hotspots of germ transmission by touch. In this paper, we propose an authentication method for physical access control by using a Quick Response (QR) Code Powered Setup. This low-cost method facilitates quick implementation by only requiring the smartphones of its employees. The main motive is to help organizations in tracking and prioritizing the safety of its employees when entering the organization and facilitating seamless human resource management. This system uses an encryption algorithm that assures a secured flow of the programmed events, avoiding any external mal-hindrance. The QR code is transmitted through a carrier network, thus enabling faster operations. The estimated duration between scanning and verification is approximately 2–3 s before the barricades get unlocked. This system is feasible for accessing gadget/tokens in semi-restricted public places and venues demanding a record of individuals using their services. QR code reading is unambiguous, as it only demands proximity of the reader device to the user's screen, thereby trenching any chances of fallacy. This technology is proficient and expedient in ways such as higher data storage capacity, curtailed implementation cost, technical simplicity, extensive use, and is globally available. Varied compatible sequencers and extraneous features can be accumulated in this ecosystem. The proposed system is demonstrated with a simple UI that can be upgraded in scale when implemented. The validation of the proposed system is measured with the SUS scale among a set of users.

Keywords Smart technologies · Smart lock · QR based system · User tracking · Occupational sectors (informal and organized)

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1 Introduction

All organizations have made increasing user privacy and authentication a priority. Users' data and personal information have become extremely valuable. As a result, businesses have had to think of new ways to protect their users' data. As a result, a portion of the company's budget goes on data security. In case of data theft, a huge loss is incurred by the company.

Getting access to a company's workplace, devices etc. requires authentication of the users. It becomes costly and dreary for an organization to provide an extra device for this authentication and manage the daily admissions of every employee. So, a less costly and innovative design method is needed for this very purpose.

The present paper tries to solve the above problem of costly products for authentication; providing a handy and quick access to the required information for the users via QR Code.

1.1 What Is QR Code?

The Quick Response (QR) code was first developed in 1994 by Denso Wave Incorporated, Japan [1]. Starting there on, it came into general use as a distinguishing proof imprint for a wide range of business items, commercials, and other public declarations.

According to Chang [1] a QR code is the abbreviation for *quick response code*, which is a machine-readable optical label with information on the associated item or product. The information in the QR Code is in both vertical and horizontal direction. So, the readability is all the simpler and furthermore the data which can be inserted in the QR code is more when compared to the barcodes. Barcodes contain the information in one dimension only. QR Code consists of black square dots and is capable of storing various types of data (e.g. numeric and alphabetic characters, kanji, kana, hiragana, symbols, binary, and control codes). Additionally, a QR code can store a maximum of 7089 characters in one symbol. One example of the QR code is shown in Fig. 1.

Chang [1] also explained the five types of QR codes which are: (A) QR code model 1, (B) micro QR code, (C) iQR code, (D) SQRC, and (E) logo (Figs. 2 and 3).

Fig. 1 Example of a QR code. *Source* Flickr [2]

Fig. 2 Types of QR codes

Fig. 3 A QR (Quick Response) code symbol of the size that can encode 300 alphanumeric characters. *Source* https://www.qrcode.com/en/ [1, 3]

These are the basic features which are targeted by the applications using QR codes. The only assumption is that the user usually owns a smart device like smart phone, smart watch and any other smart equipment. With the increasing popularity of handheld smart devices, it has become very common to find such devices with 90% of the users. This paper tries to answer two questions mentioned below:

1. How to utilize technology to achieve a less costly solution for different authentication problems for users?
2. How can this help in improving the health of the individual users?

If there is quick response and scanning of user information, then there is less chance of crowds at the entrance and exit of the premises. This in turn helps in curbing the spread of viruses and infection among the users. The second question tries to address humanizing the users to the work environment in a safe way.

The paper is divided into 6 sections. Section 1 gives some brief introductions to the problem of authentication and the idea of solving the issue. Section 2 speaks about the literature of scanning and getting the users data into use. It also speaks to the gaps in the present usage of the devices and how to solve this problem. Section 3 is about the framework and methodology followed in this study. Section 4 describes the proposed solution. Section 5 discusses the pros and cons of the proposed solution and also the validation of the proposed solution. Section 6 concludes the paper with some future ideas of proposed solutions.

So usage of QR code as an authenticated medium is very much suitable for an organization. The next section briefly describes the related literature in usage of QR codes in various applications.

2 Related Literature

The idea of using QR code for authentication can be dated back since its creation at Denso Wave Incorporated as mentioned in Sect. 1. Some of the background study in this is described in this section.

Kao et al. [4] explains the use of QR code for authentication purposes. The authors divided the architecture mentioned in their paper into two phases. The Phase-I is to register personal information of the user and the phase-II to authenticate and use the system at a location. There is also a comparison of the system mentioned by the authors and the One Time Password (OTP) system for authorization of the data by the machine which shows that the proposed architecture is robust and takes less time to react to the scanning of the QR Code. As mentioned in the paper the same architecture can be used for various other purposes like accessing a locked door, general housing activities, cinema ticketing system and railways ticketing system etc.

Chang [1] has also mentioned in his paper that the QR code can be used in scholarly articles. In fact the QR codes are now being used in accessing the digital content of the chapters in Central Board of Secondary Education, India (CBSE) textbooks [1, 5] (Fig. 4).

Ozkaya et al. [6] discussed various factors which can affect when the user is trying to use QR Code. A study was made on the college students by the authors to see awareness of the QR codes. The users were very positive in using the QR code based on the available electronic device.

In a case study among medical practitioners [7] the QR code was tested to keep the information of the patients for easy flow of the system files among authorized persons like doctors, nurses and security, which gave a positive response. It helped the

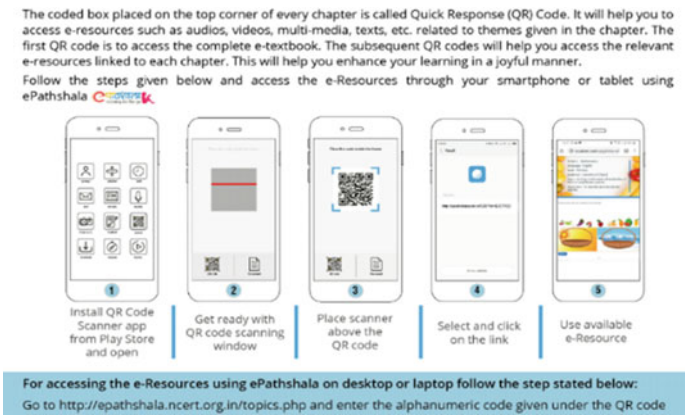


Fig. 4 CBSE textbook instruction for helping students to use QR code. *Source* https://ncert.nic.in/textbook.php [5]

important persons to keep track of the patients' daily routines and various medications given to them.

Mukherjee and Mondal [8] have applied the QR based technology to the hospitality industry where the guest receives a QR code from the hotel after booking online. This can be saved later on by the user in their phone to give them easy access to the facility when they visit the place physically. So QR code serves as the key to the room which gets updated when the guest leaves the room. This is very useful in maintaining the details of the guest along with the room details. QR Code can also be used as an end to end encryption system which provides minimal chance of data violation and works only when the hash key matches the other side of the authentication [9].

In another paper [10] an affordable technique to use the Quick response (QR) code is explained to take attendance of the students in the class. Abbas et al. [11] described the use of QR Code for the authentication to the Internet of Things (IoT) systems.

Though there are a lot of usages of QR code technology as seen in the above literature, the combination of the usage pertaining similar user's information needed at several places is still not ventured by the researchers. An attempt has been made in this paper to achieve this. The next section of the paper describes the methodology used in this study, to devise a solution to the above problem.

3 Methodology

The study follows a User centered design (UCD) approach. In this approach the user is the pivotal entity. This process takes into account the user's objectives, requirements and feedback. The process flow for this paper, started with identifying the context in use, specifying user requirements, designing a solution and then evaluating it against requirements. Figure 5 shows the UCD process. After the user research, the concept was generated through the inputs obtained from the users. Following that a prototype was made. The detailed design solution was thought of after that process. It was then validated with a small pilot study with the users.

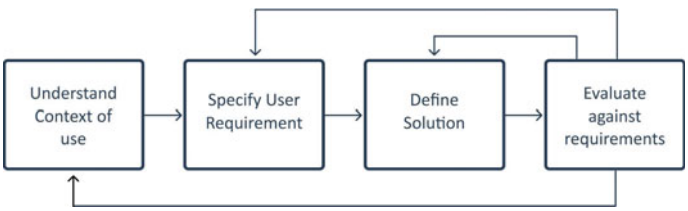


Fig. 5 User centric design approach [12]

4 Proposed Solution

The proposed solution is very simple, as it can be accommodated to any company which wants to use the application with minor adjustment in the UI. Thus making it suitable and customizable accordingly.

4.1 User Stories and Pain Points

After the User interviews and surveys the above User personas were built. The different pain points of the users were found out from the interviews, Fig. 7. Then after a lot of brainstorming the final prototype of the app was developed, named SecQR, i.e. Secured + QR. The next section explains in detail the proposed app.

4.2 About SecQr

This app facilitates the use of QR codes as virtual access cards, with utmost safety. SecQr is an app where you can add any card that uses a QR or barcode syndication system. The hardware used for implementing the app would be the RFID scanning machines that are commonly used.

The software for enabling this app is Android studio for Android devices and for IOS Devices it would XCODE (Fig. 8).

It can be your metro card, university ID card, gym membership card, office access card, and whatnot. All you have to do is that, when you reach the location, say your office entrance, open the app, click on the office access card, the mobile phone senses the optimum brightness requirement, and displays the QR code to that level of brightness and alignment. The scanner at your office quickly scans the code and you are inside your office in a split second. The process has been showcased by the diagram. The software required for implementing this part is ARDUINOIDE. Other necessary changes can be made from the receiver end, i.e., by accessing the scanners (Fig. 9).

The app even has facilities to add your other vital documents like license, Aadhar Card, PAN card etc., as this app assures your end-to-end encryption powered by 2 step verifications, including a face tracker to unlock the app, if not that then a 9-digit unique verification code stands stout, thereby avoiding any intruder trespassing. Algorithm for adding fingerprint would be first, adding fingerprint permission code to manifest file and getting access to the keyguard and fingerprint managing service of the mobile, then accessing security settings, keystore, keygenerator and creating a key while implementing the fingerprint authentication class. Thus, Fingerprint authentication involves the use of keys, ciphers and key storage combined with the features of the FingerprintManager class. Face detection can be executed by using

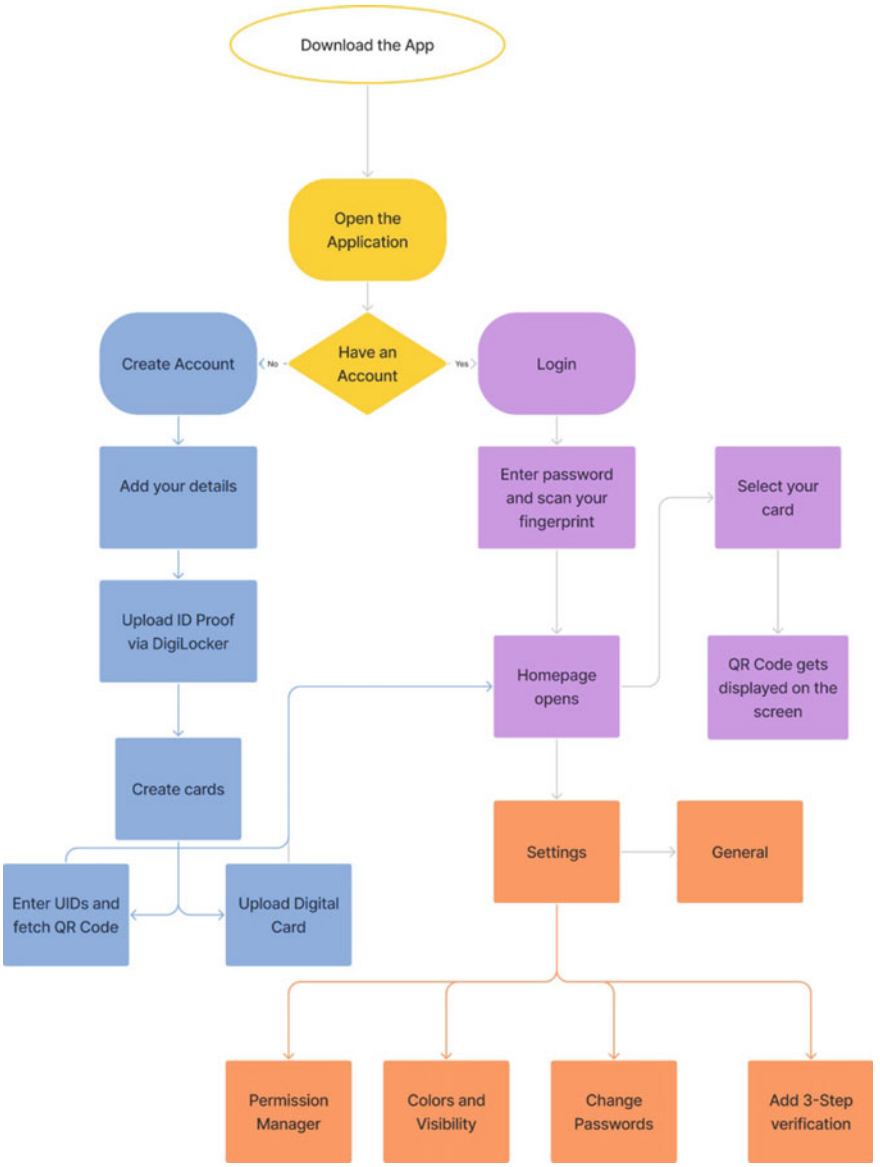


Fig. 6 User flow of the proposed application, author generated

Haar cascades is a machine learning based approach where a cascade function is trained with a set of input data. OpenCV already contains many pre-trained classifiers for face, eyes, smiles, etc. (Fig. 10).

Inside the app, users can make dedicated folders for each of your family members, thereby avoiding misplaced/disorganized cards. In cases where identity verification

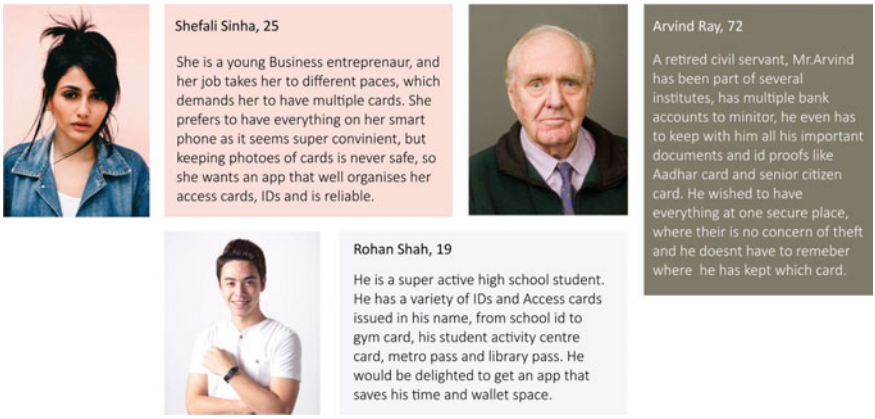
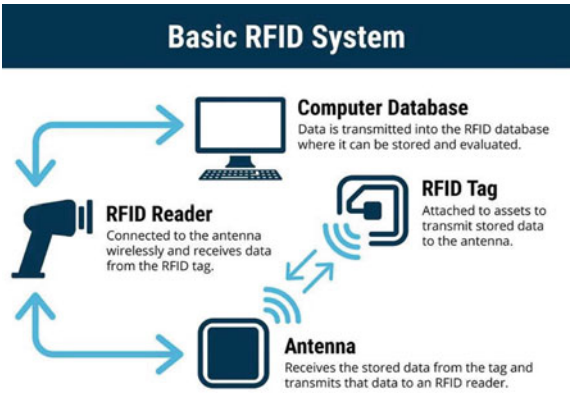


Fig. 7 User stories and pain points, author generated

Fig. 8 Overview of SecQr app, author generated

Fig. 9 Procedure for data storage



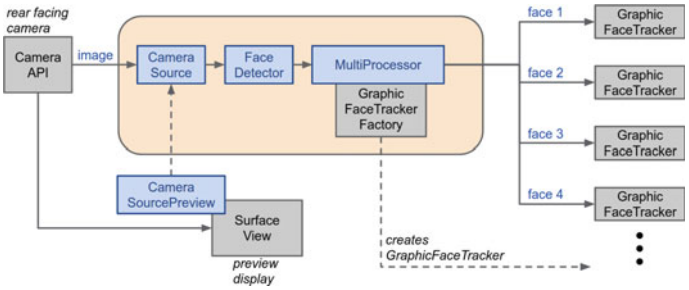


Fig. 10 Face tracker pipeline

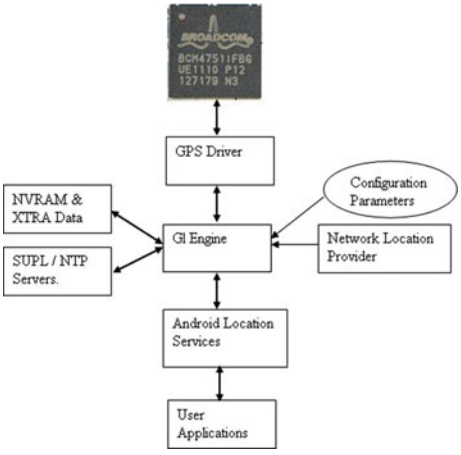


Fig. 11 Activate mobile device GPS

is required, you could have access to softcopies of all your identity cards. In case your phone gets stolen or misplaced, you can immediately lock it/block the sim card, etc. By accessing the SecQr portal from your master email and laptop/computer. The app, when it's in use, has mobile GPS activated, which helps in keeping a track of where and when you had scanned your cards. With AI assistance, the app keeps a record of which card you use, at what location, and at what time by uses modern analytics and AI workloads. Accessing Pandas that are as an open-source library which is built on the top of the NumPy library. It provides fast analysis, data cleaning, and preparation of the data for the user and supports both .xls and .xlsx extensions from the URL (Fig. 11).

It subsequently puts that access card on the top as a recommendation. The "super safe" section is for the most important cards and can be opened only with a triple verification. Also, this section would not be on the home screen, but at a secret part of the app, only known to the user. The app blocks any kind of screen recordings and takes screenshots, neither would it reflect any information when in split-screen mode.

The different screens of the app can be explained as below:

Every time the user opens the app, he has to authenticate himself by entering the unique password, Fig. 8. On forgetting the password, the app first asks you a set of predetermined questions on verifying the answers, a reset password link is sent to the authorized email address. New users are required to create their account, which is authenticated and verified by the system (Figs. 12 and 13).

SecQR requires the user to set an unusual 7-digit password, to ensure the user does not subconsciously repeat the same common 6-digit passwords otherwise used for

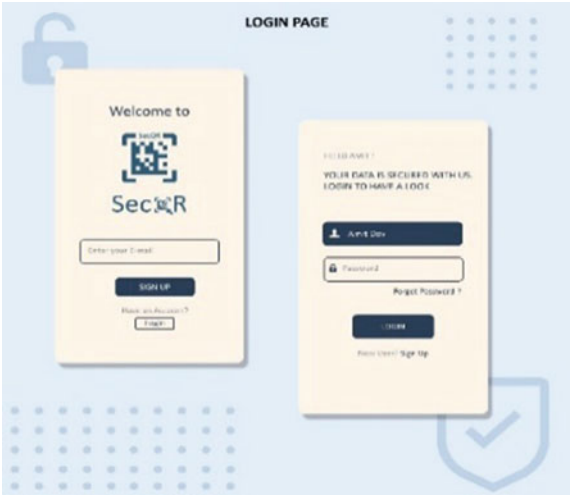


Fig. 12 The welcome and landing authenticator app, author generated

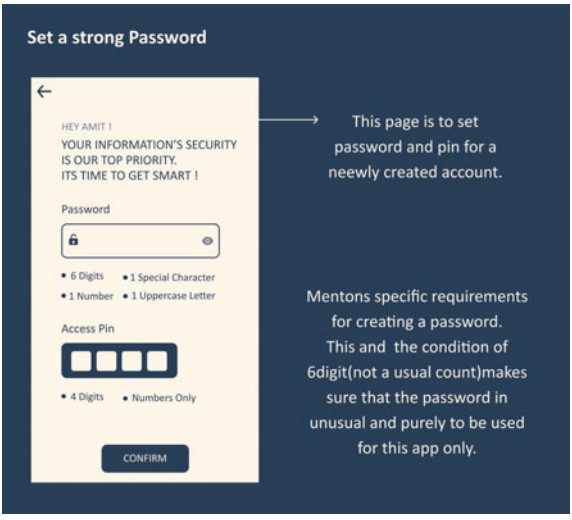


Fig. 13 The reset password page of the QR authentication app, author generated

general apps. The figures below shows a demonstration of how to enter the password (Figs. 14 and 15).

This is how a folder looks. Users can create dedicated folders; each folder would have a set of cards. Users can add, delete and even move cards between folders. Cards

Fig. 14 Authenticating the user

Fig. 15 Different cards for which the authenticator is assigned for a user

are color coded by the user, to enhance visuals and reduce cognitive load and action time.

Displayed is the image of a demo card for access to Metros. This card template displays all the essential information that validates the card's requirements. This data cannot be edited, only be updated by the user with uploading a newly issued card. On clicking the card tab, the user has to authenticate before the screen reflects the QR Code. This ensures ultimate security. School ID card from "Kids" folder.

5 Discussion

The App developed was tested with around 60 users and a SUS test was conducted for a small sample of the users (Figs. 16 and 17).

The final score of SUS came to be 85.5 which is acceptable. The two sections explain different Pros and Cons of the application.

System Usability Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Score
1. I think that I would like to use this app frequently.	○	○	○	○	◉	5
2. I found the app unnecessarily complex.	○	◉	○	○	○	2
3. I thought the app was easy to use.	○	○	○	◉	○	4
4. I think that I would need the support of a technical person to be able to use this app.	○	○	◉	○	○	3
5. I found the various functions in this app were well integrated.	○	○	○	○	◉	5
6. I thought there was too much inconsistency in this app.	○	◉	○	○	○	2
7. I imagine that most people would learn to use this app very quickly.	○	○	○	○	◉	5
8. I found the app very cumbersome to use.	◉	○	○	○	○	1
9. I felt very confident using the app.	○	○	○	◉	○	4
10. I needed to learn a lot of things before I could get going with this app.	◉	○	○	○	○	1
Respondant 1				Score : 85		

Calculation :

X - 23 Xo - 18

Y - 9 Yo - 16

Score :

SUS = (X0+Y0)*2.5

= 34*2.5

= 85

Fig. 16 Card of conducted SUS test, author generated

Fig. 17 SUS test score based on the SUS scale

5.1 PROS

1. Adding new access card QR codes and removing expired ones is a matter of a single click.
2. For professionals, who are a part of a variety of organizations, social institutions and own multiple memberships, this app would be extremely proficient.
3. The two-step verification significantly reduced the chances of a fallacy.
4. The app sends you an alert through SMS and email, every time a wrong passcode is entered twice.
5. Users can add multiple cards, and create multiple folders.
6. Users can update their QR codes with a single click.
7. Users can add tags, for every card, based on the use of the card, its purpose, the organization it pertains to. E.g. “Travel” tags for all metro, bus, taxi cards. A “Member” tag for all sports and recreational center access cards, etc.

5.2 CONS

1. Individuals who don’t have a wide range of access card requirements, won’t find this app efficient.
2. This app won’t work at places of utmost security, where even mobile phones are prohibited.

6 Conclusion

The idea of providing a secure authentication process is not new, yet to carry out it for various purposes in a solitary application is new. With the development of sophisticated technology, the future may hold some more innovative solutions involving AR and VR. The ongoing pandemic has exemplified the importance to contactless technology, thus an QR code powered alternative for our mundane access routines, assures that we have contactless transactions through crowded public places. This paper proposes one such idea, where with resources at hand, we can establish an ecosystem, where in everyplace that demands the use of an access card/security card, is dealt with by the simple use of your smartphone. In this paper a seamless access method using the QR Code was demonstrated and tested among the users to see its usability. It was found that the test group was willing to incorporate such a system, as it transpired swiftness, safety and security.

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Ergonomic Study in Information System Design of Two Major Railway Platforms of India

Jigyasa Hemant Patankar, Rajat Kamble, Suyash Krishna, and Sangeeta Pandit

Abstract Over the decades, passenger's desire to enjoy a relatively better-quality service by most popular transportation system of India that is Indian Railways. This paper aims to investigate about existing information amenities on railway platforms and find the suggestive measures to improve it, to meet with the aspirations of the passengers. The study was conducted on two major railway platform of India, Nagpur Junction and Patna Junction. Data was collected through structured and unstructured questionnaire from different stakeholders: passengers, railway officers, staff and railway station vendors. Crowd flow in the peak hours and normal hours were observed by direct observation and through video graphic method to understand the quantum of the problem at these two railway stations. The results of questionnaire and observation study on stakeholders reveals role of information system design to make the platform congestion free and provide better travel experience and quality services to its passengers. This study will be helpful in the identification of the scope where design intervention can be accommodating for a better passenger travel experience.

Keywords Travel experience design · Information system design of railway platform · Service design

1 Introduction

The Indian Railways was founded on May 8, 1845 [1]. It has become one of the busiest yet low-cost travel mode for passengers and operates the second-largest network in the world [1]. It has over 70,000 passenger coaches and more than 11,000 locomotives [1]. It plays a significant role in the social and economic development of our country. It is the most popular and affordable mode of transportation for long distance passengers in our country. To make the travel comfortable and enjoyable, Indian Railway offers several services for the passengers. These services are available both in trains and at

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the stations. Hence, with over 1.4 million employees, Indian Railways is one of the world's largest employers [2].

The number of passengers travelling through Indian Railways is increasing day by day. It is likely to increase by 50% by 2031, according to estimates projected in the National Rail Plan 2020 [3]. Due to it, Railway service providers are unable to meet the needs and demands of passengers. Analysing the past trends, it has found that in the passenger segment, maximum growth has been witnessed in the AC-3 category of passengers at an annual compound growth of 10.33% between 2009 and 2018 while there has been 6.7% growth in AC-1 and 6% in AC-2 class. The executive chair segment nearly 12% increase [3]. All this indicates that people want to travel with comfort.

In Vision 2022 plan, Indian Railways aims to develop stations and platforms with world-class facilities [3]. Railway platforms are the most important factor for consideration in the passenger travel experience. Passengers spend maximum time waiting, boarding and alighting the train. In a research study it was reported that the railway stations had no proper signage for disabled causing difficulty to locate the entry and exit which sometimes resulted in slipping and tripping of disabled passengers during rush hours [4]. It was also found that the important information on the display boards were not visible as they are hanged at remote location and were in a poor condition [4]. In the same research it was also stated that, for illiterate people to understand and read instructions, information should be in the form of pictorial so that languages will not become a barrier. In Fig. 1, the signages for platforms are in Hindi for "platform" and English "4 and 5", which is difficult for an illiterate person. There is a need to work on using pictures in all signs to convey meaning [4]. It was also found that the signage systems were not adequate considering Indian rural and semi urban areas [4]. In another study it was found that some signages can confuse the older people to poorly comprehend the message, thus increasing accident risk, they also stated improvement in such information system can reduce the risks of accidents [5]. Research stated that the signage involving human forms were found to produce difficulty in comprehending the message [4, 6]. Digital displays during night as shown in Fig. 2 are not easily readable, only large fonts can be recognised

Fig. 1 Overbridge at Nagpur junction

Fig. 2 Platform 1 during night at Nagpur junction

Fig. 3 Train schedule display and enquiry counter at Patna junction

well. Train schedule display in the ticket counter area, shown in Fig. 3, have all instructions in one colour making it difficult to read for passengers in hurry, ultimately crowd gathers around it in peak hours. Similar observation was done in the context of railway platform information system suggesting need to improve the signages and other information system amenities keeping rural and semi urban India into consideration. Thus, a research study is required in this area to study the information system amenities to understand its scope of improvement.

The research outcomes can be used to measure the performance of the amenities and will be helpful to develop plans for improving the amenities in terms of effectively communicating the important information. The main objective of this study is to understand the passenger's aspirations by investigating the awareness and satisfaction in using existing amenities on the two significant junctions of the Indian Railways; Nagpur and Patna Junction. This study aims to identify the need of design solution which can be helpful to make the platform congestion-free and provide better travel experience and quality services to its passengers.

2 Methodology

To conduct the study, two major junctions of our country, Nagpur junction and Patna junction were chosen. Nagpur Junction operated by Central Railway, lies on Howrah–Mumbai and Delhi–Chennai Trunk line of the Indian Railway. Double diamond crossing lies in Nagpur. Patna Junction operated by East Central Railways, lies on busiest rail route New Delhi–Kolkata. It connects western zone and rest of India to the eastern zone [1].

There are some limitations in conducting this study due to the lockdown situation resulting a smaller number of respondents participating in the study from the two places. In this study, 70 respondents of different age groups and occupational backgrounds were selected randomly. Among the total 70 respondents, 42 were females and 28 were male. A diagnostic approach was adopted for this study. The study was carried out by observations, literature study, interviews of passengers, railway officers, staff and vendors. The direct observation method was applied to understand the functioning of amenities. Behaviour of the passengers in the station was done by shadowing method.

The questionnaire was prepared for elected amenities like help desk, platform display, train announcements, reservation chart display, train schedule display, platform enquiry machine and signage system based on their accessibility to the passengers. A structured questionnaire was used to collect data, which included demographic questions, awareness-usage, and their satisfaction and experience. For awareness-usage, yes/no type questions were asked. A 5-point Likert-type scale was used for satisfaction level where 1 indicates least satisfied, 3 indicates satisfied and 5 indicates highly satisfied [7, 8]. Open-ended questions were asked to seek suggestions from respondents to improve the platform and station information amenities.

For statistical analysis, basic statistics including total, mean and percentages were calculated. The statistical differences in the awareness of different amenities concerning different demographic characteristics (age groups, occupation, frequency of visits) were found using the chi-square test. Here $p < 0.001$ were considered statistically highly significant and $p < 0.05$ was considered statistically significant throughout the study.

3 Results

3.1 Demographic Profile

Participants were randomly selected due to lockdown. The respondents of the survey were from all age groups, but maximum 59 participants were from the age group of 21–30. Respondents were mostly students or employed. Students were 25 and employed were 23 of the total survey participants. Out of total respondents, 65

Table 1 Demographic data of survey participants

Total survey participants		n = 70
Category	Sub-category	n (Percentage)
Gender	Female	42 (60%)
	Male	28 (40%)
Age group	21–30	19 (27.1%)
	31–40	16 (22.9%)
	41–50	15 (21.4%)
	51–60	11 (15.7%)
	60+	9 (12.9%)
Occupation	Student	14 (20%)
	Employed	28 (40%)
	Unemployed	13 (18.6%)
	Self employed	9 (12.9%)
	Retired	6 (8.6%)
Frequency of travel	Daily	14 (20)
	Weekly	13 (18.6%)
	Monthly	11 (15.7%)
	Occasionally	32 (47.7%)
	Never	–
Reason of travel	Business	6 (8.5%)
	Personal	48 (68.6%)
	Social	7 (10%)
	Leisure	9 (12.9%)
	Other	–

occasionally travelled by train, while 48 participants travelled for their personal reason (Table 1).

To analyse the awareness-usage and satisfaction level of passengers, mean has been calculated for each amenity. For the calculation of mean, affirmative values are considered.

3.2 Awareness Level of Passengers

Table 2 shows Awareness level of Information system by passengers at Nagpur and Patna Junction considering different demographic characteristics of the passengers. The statistical differences among the different demographics groups were found to be insignificant for the amenities: Platform display, train announcement, train schedule display board and signages as most of the passengers were aware of these amenities.

Table 2 Awareness level of passengers with respect to the demographic characteristics

Classification variable	Following are the information related amenities considered in the study													
	'May I help you' desk		Platform display		Train announcements		Reservation chart display		Platform enquiry machines		Train schedule display board		Signage	
	N (%)	*P*-value	N (%)	*P*-value	N (%)	*P*-value	N (%)	*P*-value	N (%)	*P*-value		*P*-value		*P*-value
Age														
21–30	11 (57.9)	0.629	19 (100)	0.445	19 (100)	–	17 (89.5)	0.012*	13 (68.4)	0.19	18 (94.7)	0.494	18 (94.7)	0.108
31–40	12 (75)		16 (100)		16 (100)		9 (56.3)		12 (75)		14 (87.5)		16 (100)	
41–50	10 (66.7)		14 (93.3)		15 (100)		7 (46.7)		12 (80)		11 (73.3)		15 (100)	
51–60	9 (81.8)		11 (100)		11 (100)		4 (36.4)		10 (91)		9 (81.8)		9 (81.9)	
61+	7 (77.8)		9 (100)		9 (100)		3 (33.3)		4 (44.4)		8 (88.9)		7 (77.8)	
Occupation														
Student	14 (100)	0.02*	14 (100)	0.823	14 (100)	–	13 (92.9)	0.002*	10 (71.4)	0.00**	13 (92.9)	0.22	14 (100)	0.417
Emp	23 (82.1)		27 (96.4)		28 (100)		13 (46.4)		25 (89.3)		23 (82.1)		28 (100)	
Un-emp	4 (30.8)		13 (100)		13 (100)		4 (30.8)		4 (30.8)		13 (100)		13 (100)	
Self-emp	9 (100)		9 (100)		9 (100)		8 (88.9)		9 (100)		6 (66.7)		9 (100)	

(continued)

Table 2 (continued)

Classification variable	Following are the information related amenities considered in the study													
	'May I help you' desk		Platform display		Train announcements		Reservation chart display		Platform enquiry machines		Train schedule display board		Signage	
	N (%)	*P*-value	N (%)	*P*-value	N (%)	*P*-value	N (%)	*P*-value	N (%)	*P*-value		*P*-value		*P*-value
Retired	5 (83.3)		6 (100)		6 (100)		2 (33.3)		3 (50)		5 (83.3)		6 (100)	
Visits														
Daily	13 (92.9)	0.01*	14 (100)	0.752	14 (100)	–	14 (100)	. 029*	13 (92.9)	0.03*	12 (85.7)	0.972	14 (100)	0.37
Weekly	12 (92.3)		13 (100)		13 (100)		13 (100)		12 (92.3)		11 (84.6)		12 (92.3)	
Monthly	5 (45)		11 (100)		11 (100)		11 (100)		6 (54.5)		9 (81.8)		9 (81.8)	
Occ	19 (59.4)		31 (98.6)		32 (100)		13 (40.6)		20 (62.5)		28 (87.5)		30 (93.8)	

Emp—Employment, occ—occasionally, *Indicates $p < 0.05$, and **Indicates $p < 0.001$

For the age groups, significant difference was found for the amenity Reservation chart display. It was found that the higher age groups 41–50, 51–60, 61+ were unaware of Reservation chart display ($p < 0.05$).

For the Occupation classifications, significant difference was found for the amenities: "May I help you" desk, reservation chart display and platform enquiry machines, under "May I help you" desk ($p < 0.05$). It was found that passengers belonging to unemployed class (30.8%) report significantly less awareness than the other classes. Under reservation chart display ($p < 0.05$), it was found that the passenger belonging to unemployed (30.8%) and retired (33.3%) reported significantly less awareness than the other classes. Under Platform enquiry machines ($p < 0.001$) it was found that the passenger who were unemployed (30.8%) showed high significance of unawareness compared to the other classes.

For the classification based on frequency of visits significant differences was found for amenities: "May I help you" desk, reservation chart display and platform enquiry machines. For "May I help you" desk ($p < 0.05$) it was found that passengers who visited monthly (45%) or occasionally (59.4%) reported significantly less awareness than the other classes. While for Reservation chart display ($p < 0.05$) it was found that the passengers who visited occasionally (40.6%) reported significantly less awareness than the other groups, under Platform enquiry machines ($p < 0.001$) it was found that the passenger who visited monthly (54.5%) or occasionally (62.5%) reported significantly less awareness than the other classes.

3.3 Satisfaction Level of Passengers

Table 3 shows mean of satisfaction level of Information system by passengers at Nagpur and Patna Junction. At Nagpur junction, frequency of announcements has maximum satisfaction level with mean value of 3.02, which shows that respondents are satisfied with this service, while the lowest satisfaction level is for help desk with

Table 3 Mean of user satisfaction level of passengers at Nagpur and Patna junction

Information system amenity	Mean of user-satisfaction level	
	Nagpur junction	Patna junction
'May I help you' desk	2.26	2.35
Platform display	2.96	3.05
Clarity of announcements	2.74	2.85
Accuracy of announcements	2.8	2.8
Frequency of announcements	3.02	3.1
Reservation chart display	2.56	2.65
Platform enquiry machines	2.28	2.35
Train schedule display board	2.92	3.1
Signage	2.74	2.8

mean value 2.26. Respondents at Patna junction are most satisfied with the frequency of announcements having mean value 3.1. The lowest satisfaction level is for help desk with mean value 2.35 and platform enquiry machine with mean value of 2.35.

Field notes taken by direct observation and interviews of different stakeholders have brought to us some very important findings. Platform number display are not clearly visible in night. Train schedule display screen is the primary source of information for all passengers. Only visually impaired and elderly finds it difficult to perceive the visual information. Signages are very helpful for wayfinding for all passengers. They communicate the information to the moving viewer at one glance. Due to background noise, spoken announcements were not audible clearly and cannot perceive. High frequency of announcements usually makes it difficult for passengers to pay attention. Reservation chart display is overcrowded before train arrival. Passengers find it difficult to read and search the reservation charts. At least, help desk should be provided on each platform for passengers who are not literate, or elderly. Platform enquiry machines are usually found not functioning properly other than on Platform 1.

4 Discussion

Information system in public places like railway platforms plays a very important role in communicating vital information to the passengers, providing a proper wayfinding system, transport information, showing the locations of different places of necessity like, waiting room, canteen, washrooms, help desk, counter etc. Failure in interpreting this information may sometimes lead to accidents, risks and dependency [4–6]. In our study we found that most of the passengers were aware of the amenities such as Platform display, train announcement, train schedule display board and signages and many were found to be unaware of the amenities such as: "May I help you" desk, reservation chart display and platform enquiry machines, it was found that the older passengers of age more than 51 were least aware of Reservation chart display. In the classification by occupation, it was found that the unemployed were least aware of the amenities such as: "May I help you" desk, reservation chart display and platform enquiry machines. It was also found that the passengers who occasionally travelled on trains reported least awareness in: "May I help you" desk, reservation chart display and platform enquiry machines. Similar awareness study was done on awareness in wayfinding tools in railway platform [9].

In this study we also found that of all the amenities, the passengers were least satisfied with the usage of "May I help you" desk with mean value of satisfaction as 2.26, followed by mean value of 2.28 for platform enquiry machines, mean value of 2.56 for reservation chart display and mean value of 2.74 for signages and clarity of announcement. Similar findings have been discussed in the research papers [4, 5]. It can be seen that though passengers were aware of the signages, they were not satisfied with usage of this signage due to the different reasons such as difficulty in

comprehending, not standardised, poor illumination etc. as discussed in the research [4–6].

Limitations of this study are the smaller number of respondents considered for the study due to the pandemic situation. A larger data could help better understanding in this area of research. A proper assessment of individual signages is needed to be done for suggesting improvement in the same.

Study can be helpful in improving the existing information system. It can also help the authorities to understand passengers' aspirations and can serve as a basis for addition of new amenities like passenger safety gates which are very essential for improving travel experience of especially abled. Study of signage system will help in fast navigation, logical organisation and visual clarity of information which ultimately improves travel experience.

5 Conclusion

Since the railway platform is a crowded area, there is a high risk of accidents due to miss interpretation of messages from signage or other information systems. Thus, it is very important to study these amenities to identify the problem areas. From this research it is evident that awareness about the following amenities such as "May I help you" desk, reservation chart display and platform enquiry machines is very much needed. It is also evident from the research that passengers were not satisfied with the usage of the amenities such as "May I help you" desk, platform enquiry machines, reservation chart display and signages.

Signages helps us to present complex data with an icon or picture clearly understood by all. New amenities like platform safety gates are desired. Train schedule display can have colour codes for late, arriving and departure trains. An ergonomic intervention is needed in this area to improve these amenities for better passenger satisfaction.

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Perception and Continuous Intention of Wearable Fitness Trackers Among Different Age Groups: En Route Towards Health and Fitness

Swati Sarkar and Debkumar Chakrabarti

Abstract There is a significant societal change in the world with the growth in the ageing population. Older adults are likely to accumulate some health sternness with age, often leading to the functional disability with time. Assistive devices are an excellent resource in such cases, but independence is compromised to some extent. However, wearable fitness trackers (WFT) play a significant role in motivating people to indulge in a healthy lifestyle avoiding vulnerabilities in the old age. Despite the sales of WFT being large-scaled, it faces challenges in its sustainable usage. This paper discusses the various challenges faced by older adults through the ageing process. Correspondingly, it addresses the effects of health and fitness intervention in the enhancement of their living standards. It highlights the methods and results of the study conducted on people aged between 18 and 75 + years towards the Behavioural and Continuous Intention of WFT. As a solution, the paper highlights the positive prospects of WFT as an essential tool towards health and fitness and methodically addresses the sustainability issue concerning its acceptance and Continuance.

Keywords Ageing · Fitness · WFT · Expectation confirmation · Continuous intention

1 Introduction

Ageing refers to how human beings, their functions, morphology, and other features change with time [1]. Furthermore, physical and sensory impairment is perceptible among older adults with varying degrees of disability with advancements in age [2]. The world is experiencing the growth of the ageing population, and with its increase, vulnerability among older adults rises. The risks of acquiring chronic diseases and the functional declination in the vision, mobility, hearing and cognitive abilities are associated with ageing. Nowadays, it is observed that the younger adults are engaging in some physical activity; however, a more considerable fraction of the older adult

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population involves them in sedentary lifestyles, not indulging in any considerable physical activity [3]. Wearable Fitness Trackers provide an excellent route towards achieving a better way of living. These are capable of personal quantification by tracking fitness activities in a person. Also, these devices can provide basic information regarding the vital physiological changes in the body, which might require professional attention. These devices are already motivating the younger users in deriving health benefits, but despite its positive prospects, the ageing population is the most challenging group to be motivated [3]. The market survey of these wearables reveals a gradual increase in their sales, but the sustainable engagement and adherence to these products seem to diminish with time.

2 Methods

A systematic review was done to study the ageing process, its associated complications, and health and fitness intervention benefits. It also encompassed the technology intervention in health and fitness and then comprehended the evolution of technology acceptance. In addition, a study was conducted to understand people's Behavioural and Continuous Intention towards wrist-worn WFT with 31 participants, ten males and twenty-one females, over 20 years of age. The UTAUT2 questionnaires were prepared by modifying the constructs relevant for the study with questions answered through a Likert scale ranging from 1–5, where 1 and 5 stand for 'strongly disagree' and 'strongly agree', respectively. The determinants considered in the modified UTAUT2 Questionnaire to follow the Behavioural Intention were: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Price Value (PV), Design Aesthetics (DA), and Hedonic Motivation (HM). A separate Questionnaire prepared for the study of Continuous Intention (CI) incorporated the following constructs: Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Perceived Risk (PR), Design Aesthetics (DA), Satisfaction (SA), and Expectation Confirmation (EC).

3 Review on Health, Fitness and Older Adults

The most vulnerable group of society is the elderly population, exposing them to health adversities. Susceptibility to chronic diseases, infections, and disabilities is higher among older adults [4]. Various studies have shown that older adults are likely to accumulate some health severities with age, which leads to the functional disability with time.

Table 1 Risk factors of disability associated with the older adults [6, 11, 12]

Biological factors	Age, Gender, Race Height/Weight relationship, sedentary lifestyle Congenital abnormalities, chronic illness Genetic predisposition
Behavioural/Psychological/Lifestyle factors	Cultural basis Poor nutrition, use of tobacco, alcohol, other drugs Low level of motivation, Inadequate coping skills Difficulty dealing with change or stress and negative effect
Physical and environment characteristics	Home and work environments, Ergonomic characteristics Architectural barriers at homes, community, and workplace
Socio-economic factors	Low level of education and economic status Health care Inadequacy and Limited family or social support

3.1 Review on Health Degradation with Age

According to a study, 88% of the geriatric population exhibits some functional limitation, regardless of gender. Over the age of 55, on average, 45% of females and 28% of males report joint pain [5]. Moreover, the prevalence of speech disability, hearing disability, visual disability, and agility (walking, locomotion, climbing stairs, dexterity, and body movement) counts to be 4%, 10%, 56%, and 33%, respectively [6, 7]. With the due passage of time, although there is increased growth in the older adult population living in their own homes, it is distressing to register that most of the proportion lives with limitations like mobility, disability, dexterity, or restriction in their mental capacity [8–10]. Table 1 depicts the various risk factors associated with health degradation in older adults.

Growth in the older portion of the population demands proper assistance in performing daily activities [13]. Older adults also enjoy independence, like others but the vulnerabilities associated with ageing make the elderly dependent on care providers. Here, Assistive Technology (AT) plays a significant role in providing a sense of self-dependency through the various assistive aids, which selectively target different dysfunctionalities.

3.2 Assistive Technology

The older adults' periphery becomes very narrow due to the prevalence of disability, and a significant number of older adults are provided with support either by their

family members or caregivers. In them, the susceptibility of incurring injuries caused by chronic illnesses like osteoporosis or reduced protective reflexes is high, and due to this lack of control, the danger of falls is prevalent in many older adults [14, 15]. The AT has been receiving significant attention for many years now as it can compensate for the declined function, thereby helping the older adults achieve independent living and enhancing overall well-being. Table 2 elaborates the various assistive technologies availed by the people from Great Britain.

The long-term care arrangements aim to reduce the disabling effects of physical impairments and functional limitations [8]. WHO (2018) estimated that by 2030 more than two billion people will use at least one item from the available AT [16].

Assistive devices- "Any device or system that allows an individual to perform a task that they would otherwise be unable to do, or increases the ease and safety with which the task can be performed" is termed an assistive device [13, 16]. Various assistive aids contribute towards achieving daily activity goals with ease and comfort. Along with the primary assistive devices that assist the elderly in carrying out daily activities with self-dependence, various other assistive devices are available that assist them during some physical or cognitive dysfunctionalities that occurred either due to accidents, disease, or consequences of ageing. However, each device has its particular function with pros and cons.

Table 2 Assistive technology availed by older adults in Great Britain [8]

Type of assistive technology	Level of disability	
	Moderate	Severe
Mobility Aids: walking sticks, wheelchairs, walking frames, crutches, trolleys	55	78
Vision aids: ordinary stick, magnifying glass, guide dog, Braille equipment, white cane, writing frame, audibles/tactile measuring device, frame for telephone, talking-book machine, sonic aid, low vision aid	41	39
Hearing Aids: hearing aid, adaptor for telephone, adaptor for TV, adaptor for radio, flashing light for telephone, flashing light for the door, flashing alarm clock, pointer board, typewriter	21	23
Furniture or daily living aids: bed-hoist, bed poles, and ladders, cradle for bed clothes, orthopaedic mattress, ripple mattress, sheepskin mattress, other special bed or bedding, commode, Sani-chair, toilet hoist, other aids to toileting, bath seat, non-slip mat, environmental controls	28	51
Gadgets or small aids: special crockery, special cutlery, special utensils (e.g., potato peeler, tin opener), tap turner/ special taps, special door handles, pick-up aid, dressing aids, electric toothbrush, gadget to summon help	19	33
Adaptation to accommodations: ramps outside and inside instead of steps, handrails outside and inside, doors alerted for better access, e.g., widened, stair-lift, other alterations for better access, fitted furniture altered (e.g., shelves, cupboards, cooker), new bathroom or toilet added, shower installed, bath grab-rail installed, door answering/opening system	28	45

3.3 Assistive Technology Acceptance by the Older Adults

The younger adults are more into using the technology than their older counterparts, but if the technology benefit is clear, they show interest in trying and habiting the technology when a need is felt [17]. According to a study on user experiences of the assistive technologies among people over 69 years, the results suggested an acceptability model where the product quality was accompanied by the 'felt need' for assistance. Besides, an essential characteristic is that the users seek the AT to work correctly, reliably, and safely [8]. The usability determination of the assistive devices is of serious concern, despite the worldwide availability of such devices. However, a product inevitably determines its users through its ease of use [17]. Assistive technology devices are an excellent resource for people suffering from disabilities prevalent in older age. As prevention is better than cure, and if disabilities in older age can be made dissolve by some means, independence is assured, enhancing the essence of living irrespective of any generation. Studies have discovered that it is possible to eradicate the sufferings associated with older age with proper physical fitness and psychological well-being. Also, proper health care before even hitting the older age ensures healthy ageing.

3.4 Fitness Activity Intervention in Older Adults

In older age, having cognitive impairments is a common scenario, thereby increasing the risk of falls, but empirical studies reveal that daily exercise can stabilise the postural ability and prevent fall risks in older adults' falls [15, 18]. Older people are expected to live functionally for many years, but they spend their lives unmet ADL needs for the last two-third of the disabled year [19]. To overcome the adversities in the older age, maintaining health and fitness will result in health benefits.

An empirical study intervened in a strength-training program that used isotonic resistance exercise machines for 14 weeks, three days per week. The results had shown enhancement in the specific force by 19% [20]. Also, the effects of the intervention of low-to-moderate intensity exercise programs on mobility, endurance, strength, and fall rates in older adults already having some chronic impairments and prone to fall had significant positive outcomes [21]. The Progressive Resistant Strength Training (PRT) was compared with Traditional Balance Exercise (TBE) in a study, and their combination was also evaluated. The PRT group indulged in resistance training for the lower extremities' muscles while the TBE group incorporated eight-component traditional balance exercises four times per week for six months. Among the non-frail older adults, PRT intervention resulted in being more operative than TBE [22]. In a similar study, after the PRT experiment, the gait velocity was significantly increased by $11.8 \pm 3.8\%$ in the exerciser group. In addition, the total energy intake and the stair-climbing power were also enhanced in the exerciser group [23].

In a randomised trial study concerning the study factors: adherence during the trial, exercise worth, affective retorts to exercise and social backing from the exercise group, they studied the extent to which these factors directly or indirectly influenced the physical activity through the intervention of exercise self-efficacy. Results showed that self-efficacy was enhanced by the social, behavioural, and affective factors and showed higher participation at 6- and 18-month follow-up [24]. In a trial conducted by Chiello et al., they randomly assigned 46 older adults (mean age –73.2 years; 18 women and 28 men) into training and control groups. The study intended to understand the short- and long-term effects of resistance training on the memory, muscle strength, psychological well-being, control beliefs, and cognitive speed in active older adults where the efficiency of the resistance exercises was fully projected, and the maximum dynamic strength significantly increased in the training group. Also, a significant enhancement in psychological well-being was observed, and the training group exhibited significant long-term effects prominent in muscular strength and memory performance [25].

Yoga has been tremendously benefitting people from all age groups. In a randomised experimental yoga-based intervention trial conducted on the elderly from Bangalore city, in India, substantial positive benefits were witnessed after the program, approved by the Institutional Ethical Committee of the National Institute of Mental health and Neurosciences (NIMHANS). After the intervention, the delayed and immediate recall of verbal and visual memory, attention, and working memory significantly improved [26]. Fitness activity intervention has a significant positive effect on people's physical and cognitive health, irrespective of age.

4 Wearable Fitness Trackers

A Wearable Fitness Tracker (WFT) is a device that is in the form of very miniaturised hardware capable of tracking and monitoring fitness parameters, e.g., consumed calories, sleep tracking, distance walked or ran, and heart rate tracking [3, 27]. Relying on the Assistive devices merely provides the capability to regain the lost operationality, but their independence and sense of self-efficacy are compromised. Indulging in a healthy lifestyle can promise better living standards. WFT can measure such parameters which reflect the physical activity performance. Hence, such devices represent opportunities for the measurement of physical activity [27–29]. The ideology of WFT promotes physical activities and reduces sedentary behaviour [29], ensuring health and fitness. The healthcare providers are obliged to change the mode of delivery and the composition of the healthcare facilities due to an increase in social needs and industry-induced competitive pressures [30]. Here, technology has a substantial role in developing such healthcare services, and in technology, mobile devices have become a promising and essential tool with its evolution. Wearable Fitness Technology has already flooded the fitness market because of its vast potential. Also, analysis of google trends has recently reflected the tremendous increase in the searches related to fitness trackers and smart wearables. It is estimated that the

fitness bands, smartwatches, smart wearables will account for nearly half of the overall wearable unit sales worldwide [31]. Research suggests that the global market of wearable devices shall significantly be anticipated to grow each year by 78% [3].

4.1 Wearable Fitness Trackers and Physical Activity

According to industrial and academic research, activity trackers can significantly increase physical activity by monitoring progress and other behavioural change techniques. Goal setting and self-monitoring are excellent encouragement in self-efficacy promotion and interventions on physical activity [32]. It is a very well-established fact that physical activity is a crucial aspect in managing and preventing various chronic ailments over a lifetime. Moreover, it has tremendous health benefits in old age and shows positive effects in also very old age [33]. Engaging in various activities and group activities benefits people from all age groups. It benefits the older adults' physical and cognitive health, promoting healthy ageing. A study revealed that the subjects' average bodyweight having some chronic disease decreased after using the fitness tracker for three months [34].

4.2 Perception, Acceptance and Continuous Intention of Wearable Fitness Tracker

An increase in health consciousness among people has significantly increased the use of fitness devices [3]. Although its use is not limited to any particular age, its intensity might vary in different age groups. Several factors play significant roles in keeping adherence to a service or product. Various models have been introduced in technology towards its acceptance, which argues the factors responsible for consumers' behavioural acceptance.

Technology Acceptance- Fred D. Davis introduced the Technology Acceptance Model (TAM). It provides an information structure theory that represents the users' acceptance and usage of technology. It delivers the framework that regulates the possibility of technology acceptance and adoption [3, 28]. According to TAM, perceived usefulness and perceived ease of use are the two key factors predicting a technology's acceptance and adoption [35]. Perceived usefulness depicts "the degree to which a person believes that using a particular system will enhance his or her performance," and perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" [3, 36]. Perceived health benefits also play a significant role in determining the acceptance of healthcare technology. It signifies the impression of customers' perspective towards exercise and fitness [3, 28]

However, TAM does not include all the crucial determinants to predict the technology with extreme accuracy. Venkatesh et al. proposed a model, namely Unified Theory of Acceptance and Use of Technology (UTAUT), in 2003, as a new theory of acceptance of Information Technology. Formulation of UTAUT considered eight well-established models: Theory of Planned Behaviour, Technology Acceptance Model, The Model of PC Utilisation, Theory of Reasoned Action, Combined Technology Acceptance Model and Theory of Planned Behaviour, Motivational Model, Diffusion of Innovation Theory, and Social Cognitive Theory. Performance Expectancy, Effort Expectancy, Facilitating Conditions, and Social Influence constituted the new model.

According to certain scholars, specific critical determinants were discounted in the UTAUT model. Despite having its higher quality explanatory power, it accounted for the incompatibilities in the framework with its new predictors [3, 37]. Venkatesh and Thong modified the existing model UTAUT to UTAUT2 by incorporating three more constructs: Price value, Habit, and Hedonic Motivation and considered a relatively effective and widely used model in determining technology acceptance.

Expectation Confirmation Theory (ECT)- It is widely used to study consumer satisfaction and post-purchase behaviour. According to ECT, the Intention of consumers to continue service use of a product is primarily determined by their level of satisfaction with prior experience with that product or service.

Figure 1. above represents the expectation confirmation model where the plus and minus signs represent that the constructs are either directly or inversely influenced by the other. Here 'satisfaction' is the key factor in building and maintaining the long-term consumer relation base. The 'expectation' is an additional determinant of satisfaction, and lower expectance and higher performance may lead to confirmation and Continuance of the service. Alternatively, a higher level of expectation may cause a discontinuance of the product due to disconfirmation. Confirmation is expressed as directly related to perceived performance and inversely related to expectation [38].

Continuous Intention of Wearable Fitness Trackers- It has been experimental from studies that those adults who have been observed to have increased daily

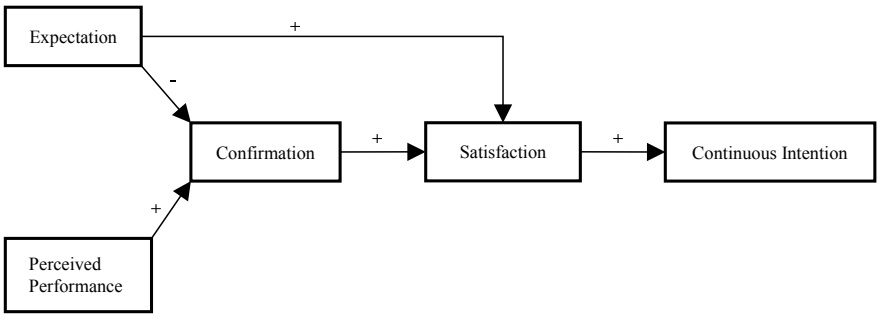

Fig. 1 Expectation confirmation model

activity levels who started using the wearables. In a study of 7-month duration, people between 36–73 years were provided with WFT, and it was observed that the participants continued using it even after seven months [32]. However, a study discovered that out of 8 adults who were 75 years of age or older experienced certain technical issues with the trackers, restricting them from garnering any information. Although the adoption of WFT is on a vast scale, it suffers the critical challenge in its sustainable usage. Studies reveal that users are likely to abandon the wearables in less than six months, where the abandonment rate is nearly 30% [39]. A possible explanation for the abandonment of these devices can be the lack of capability to inspire action. For continuance intention, experiential and emotional satisfaction plays a significant role. Despite the device being helpful, it does not succeed to emboss an expressive influence on the users' behaviours and developing into habits. Determination of such an effective engagement process incorporated during the design process itself in the WFT can motivate its users and continue its usage, which is indispensable in making a sustained value of the product [39].

5 Results

Out of thirty-one participants, 58.1% were actively involved in fitness regimes, and 35.5% owned a WFT in this study. The correlation between the various constructs and the Behavioural and Continuous Intention is shown in Tables 3 and 4, respectively.

Performance Expectancy, Social Influence, Design Aesthetics and Hedonic Motivation strongly correlated with the Behavioural Intention and Perceived Ease of Use, Perceived Usefulness, Hedonic Motivation, Satisfaction, and Expectation Confirmation strongly correlated with the Continuous Intention of the WFT among the users

Table 3 Correlation between the constructs and the behavioural intention

Constructs		PE	EE	SI	FC	PV	DA	HM
BI	Pearson Correlation	0.707**	0.087	0.479**	0.014	−0.131	0.487**	0.542**
	Sig. (2-tailed)	0.000	0.641	0.006	0.941	0.482	0.005	0.002

Table 4 Correlation between the constructs and the continuous intention

Constructs		PEOU	PU	PR	DA	HM	SA	EC
CI	Pearson Correlation	0.696*	0.767**	−0.376	0.245	0.630*	0.872**	0.607*
	Sig. (2-tailed)	0.017	0.006	0.255	0.467	0.038	0.000	0.048

in this study representing these as the essential constructs for its acceptance among people.

6 Discussion

Physical fitness and psychological well-being can enable healthy life in all age groups, and before even hitting the older age, appropriate health care shall result in gifting and ensuring a healthy ageing process. In today's world, young people are mainly health and fitness conscious, but older adults nurture the negative stereotype of ageing and often keep themselves distant from the fitness routine [3]. WFT have shown a significant increase and indulgence of young people into a healthy lifestyle. However, it is believed to provide a positive intention to people from all groups in pursuing fitness routines with the help of these devices, although the ageing population shows the most extensive resistance towards being motivated in doing physical activity intending fitness [3]. The younger generation is more active towards availing the digital care. The older population is left at the periphery of the wearable tracker industry [32]. Various constructs used in the UTAUT2 and Expectation Confirmation Theory Models and their moderators play a mediator in predicting the Behavioural and Continuous Intention of WFT. Results show that Hedonic Motivation, Design Aesthetics, Performance Expectancy and Social Influence play a significant role in determining the People's Behavioural Intention towards WFT. In addition, Perceived Ease of Use, Perceived Usefulness, Satisfaction, Hedonic Motivation and Expectation Confirmation are crucial factors in determining the sustainable adherence to WFT intending its Continuous Usage.

In conjunction with the established constructs, Self-efficacy can provide some insight into the Behavioural and Continuance Intention of WFT as it reflects how people's actions are affected by their self-belief. Also, self-efficacy plays a crucial role in predicting the success of health intervention in both the short- and long-term [39]. Although wearable fitness trackers' sales are large-scale, it faces challenges in its sustainable usage. Reports say that users tend to abandon wearable devices in less than six months. More research shall be encouraged to understand the underlying cause of such disruption, and therefore, the designers shall put relevant interventions intending the continuous and prolonged use of the WFT, which has already proved its essentiality as a tool in ensuring a healthy life. The amalgamation of Ergonomic considerations during the design process into the technology shall play an essential role in addressing these issues. It acts as the 'no man's land between architecture and health and safety, computer science and consumer product design, engineering and medicine [40]. Likewise, it shall ensure a better bridging between the technology and human factors, thereby positively influencing the consumer behaviour towards the sustainable adherence to such products.

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Participatory Design of a Computer Mouse

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Abstract Intensive use of the computer mouse is associated with an increased risk of musculoskeletal disorders. Due to prolonged use of the mouse with a wrist posture that deviated from its relaxed posture, users may experience fatigue, discomfort, and even pain on the wrist and hand. Both size and shape of the mouse can be a cause of this associated discomfort. In this work, we have followed a participatory-design approach to propose a design concept and develop a vertical pointing device prototype that offers a comfortable right-handed grip that resembles the relaxed hand posture. This work aims to understand user participation during the design process and how their involvement helped evolve the device concept that enables comfortable grip and novel interaction opportunities. We started the participatory design process using clay mockups to finalize the initial shape. After finalizing the initial shape, we made further modifications based on user feedback. After two iterations, we completed the design and conducted a user study to investigate perceived comfort and pressure on the wrist. We found that the grip on the device was comfortable for participants with medium and large hand sizes, and the majority of them reported no pressure on the wrist. The device allows users to keep their hands in a more ergonomically desired posture. It offers novel interaction modalities as an alternative to the button-based controls of a typical computer mouse. We believe this work will help interaction designers and researchers design ergonomic pointing devices enabling multimodal input interaction.

Keywords Participatory design · Vertical pointing device · Ergonomic mouse · Multimodal input · Deformable devices

1 Introduction

The computer mouse is often used as a pointing device for input interaction with the elements of the graphical user interface (GUI). While working with a computer

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mouse, providing input with precise and accurate cursor movements requires continuous gripping and pressing the mouse's buttons. In such scenarios, stress and strain on fingers and wrist may develop during excessive use [1, 2]. As a result, users may experience fatigue, discomfort, and even pain in holding hands and wrists. The intensive use of a computer mouse is associated with an increased risk of musculoskeletal disorders that can affect the productivity of users [3]. This discomfort associated with the prolonged use of a computer mouse may lead to diseases like Tendinitis, Bursitis, and Carpal Tunnel Syndrome (CTS) [4–7]. According to literature, 2.7% of people are affected by Carpal Tunnel Syndrome [8]. Among computer professionals, one of the common musculoskeletal disorders includes CTS [4]. Too frequent use of a computer mouse where the size and shape of the device do not allow ergonomic hand posture causes discomfort in the muscle and tendon system of the hand [5, 9]. The most natural and relaxed position for a hand placed on a desk by a sitting person is an upright position: the little finger side of the hand rests on the desk, and the fingers and palm generally define a vertical plane [10].

Therefore, holding a typical non-vertical computer mouse requires the wrist and forearm to be twisted out of their natural and relaxed position. It requires a constant muscular force that is applied to continue that twisted posture. Moreover, for a three-button mouse, the fingers used to press these buttons are often kept in constant upward tension while moving the mouse to avoid unintentional input. In addition, the horizontal hand posture supported on the desk by the wrist also develops pressure on the wrist, which may also lead to fatigue, discomfort, and pain over time [11]. These difficulties associated with using a typical mouse indicate the need for a device that allows a comfortable grip on the device with relaxed wrist and hand posture.

Existing literature provides us a large set of device concepts that are later reflected on different commercial products that offer support surfaces for several parts of the hand [10, 12, 13] along with an inclination of the device itself [10, 14] for a comfortable handgrip. For offering higher user satisfaction, design decisions can be made with a better comprehension of user needs [15]. The user's participation in the design process provides a better understanding of user needs and usability [16]. In this work, we focused on a participatory design approach to propose a computer mouse that enables a comfortable right-handed grip on the device. This work primarily aims to understand user participation during the design process and how their involvement during multiple iterations helped evolve the device concept.

We conducted the first user study to identify user-preferred right-handed grips for comfortable wrist and hand postures and preferred shapes for the pointing device by using clay mockups. With the results from this first study, we developed the first prototype. After two iterations, we achieved the final device concept (Fig. 1) and evaluated user-perceived comfort and pressure on the wrist. We found that the participants with medium and large hand sizes found the prototype comfortable to use, and the majority experienced no pressure on the wrist. The proposed shape of the mouse allows users to keep the hand in a more ergonomically desired hand posture. Overall, all the participants enjoyed using the vertical pointing device and proposed novel interaction opportunities as an alternative to the button-based controls of a typical computer mouse.

Fig. 1 Front view of the prototype (left) and the user is holding the final prototype (right)

2 Literature Review

Researches on wrist extension postures and carpal tunnel pressures developed due to computer mouse use have been carried out since it has become an integral part of human–computer interaction [1, 2]. Gart [12] proposed an ergonomically shaped mouse to prevent or reduce hand muscle fatigue. This mouse offers several support surfaces to rest the mid-palm of the hand, the thenar pad of the hand, the hypo-thenar portion of the hand, the distal volar pad of the forefinger, the distal volar pad of the thumb, middle phalanges of the ring, and little fingers. According to the author, these support surfaces will allow continuous use of the computer mouse for a long time. Later, Lo [10] proposed an ergonomic computer mouse with support surfaces for all the fingers while operating the mouse. These support surfaces and the shape of the proposed device concept will allow users to keep their hands in a naturally upright and relaxed position without twisting the hand, wrist, or forearm. According to the author, this upright posture will minimize or eliminate fatigue, discomfort, and pain even after a long period of continuous use. Robinson [13] also proposed using a support surface for the comfortable use of a computer mouse for a long duration. This proposed device concept contains a built-in foam rubber wrist and palm support to minimize pressure. Tajiri [17] proposed a computer mouse concept for preventing CTS. The device provides a support surface for the palm with a curved upper surface to prevent significant bending of the wrist. Segalle [6] proposed an orthopedic computer mouse where the shape of the device concept was generated from a mold of the human hand to provide a support surface for the fingers. According to the author, the shape will eliminate the adverse effect of using a computer mouse.

Saez et al. [14] proposed a device concept that offers support surfaces for the wrist and palm. The most important feature of this device concept is enabling users

to position their hands in a more ergonomically desirable position at an angle of about 45° to the work surface. The device's bottom surface is designed so that it can accommodate both left and right-handed users with equal inclination. Moreover, the device supports adjustable lengths to cater to users with different hand sizes. Van [11] proposed an ergonomic computer mouse for the user's ergonomic benefit and optimal comfort. This mouse is an elevated mouse attached to a fixed base structure. The proposed device concept allows position adjustment along three axes to meet individual user ergonomic and comfort requirements. In addition, the palm support surface can also be adjusted to adapt to different hand sizes of users. Miguel et al. [18] proposed a pointing device based on the requirements, recommendations, and guidelines focusing on ergonomic and usability considerations. This device offers a curved support surface for the palm and fingers. The opposite support surfaces for the thumb and rest of the fingers allow stable movement of the device. The inclination of 30° reduces the required rotation on the wrist and forearm. Although several device concepts have been proposed in the literature, there is limited research that reported the involvement of users in the design process. This work aims to understand user participation in the design process and propose a pointing device concept that enables comfortable grip and novel interaction opportunities.

3 Preliminary Study

We conducted a preliminary study with twenty university students (14 males and 6 females between the ages of 18 to 25 years $M = 21.7$ and $SD = 2.25$). According to the participants, they do not have any existing pain in their hands and wrists. Since the prevalence of Carpal Tunnel Syndrome is higher in the age group above 30 years [4], we selected a younger age group to reduce the possibility of including participants with unnoticed existing conditions of musculoskeletal disorder. This preliminary study aims to understand their usage of a computer mouse, the type of mouse used, and issues associated with continuous use of the mouse. All the participants use a computer mouse while working on a desktop, and 65% of participants often use a mouse while working on a laptop. We found that 95% of participants use the typical non-vertical optical computer mouse (60% wireless and 40% wired). In contrast, only one participant uses an ergonomic mouse for gaming purposes and a pen tablet for drawing. The majority of the participants who use a computer mouse while working on a laptop reported that they prefer to use a mouse while using a particular set of applications that require precise cursor movement. The most common issues due to prolonged use of computer mouse reported by the participants include pressure and pain on the wrist, where the fingers join the palm, and the joints of the index and middle fingers. These results motivated us to conduct the following study to propose a pointing device that allows natural hand posture while operating with the mouse and explore its interaction opportunities through a participatory design approach.

4 Participatory Design of a Computer Mouse

This section presents the steps involved in achieving the design of the prototype and the evaluation of the prototype. First, we have reported the preparation of the initial clay mockup and the iterative process of refining the design through the involvement of the participants. Finally, we evaluated the level of user-perceived comfort and pressure on the wrist.

4.1 User-Preferred Grip Using Clay Mockup

We conducted this study to identify the user-preferred right-handed grip on a pointing input device with a comfortable hand posture. Ten right-handed university students (7 males and 3 females between the ages of 19 to 25 years M = 22 and SD = 2.11) participated during the design process. According to the participants, they do not have any existing pain in their hands and wrists. We measured their hand length (ranging from 15.7 to 21.2 cm with M = 18.41 and SD = 1.82) and hand width (ranging from 7.5 to 10.2 cm with M = 8.91 and SD = 0.95) to address participants with different hand sizes. In this work, we considered three groups of hand sizes small (hand length less than 17 cm and hand width less than 8.5 cm), medium (hand length 17 to 20 cm and hand width 8.5 to 10 cm), and large (hand length more than 20 cm and hand width more than 10 cm). In the selected participant group, there were 3 participants with small hand sizes (2 female and 1 male), 4 participants with medium hand sizes (1 female and 3 male), and 3 participants with large hand sizes (all male).

A ball of clay was given to the participants and asked to mold it into a comfortable shape. They were asked to propose a shape for right-handed users that can be used as a pointing device to interact with the computer. We asked the participants to explore several forms and report the most preferred one. Users were encouraged to give it a shape for comfortable gripping that keeps the wrist and elbow closer to a relaxed posture while the forearm is lying on a table. We also asked the participants to explore input interaction with the proposed pointing device that does not affect the comfortable grip. The majority of the participants preferred a shape that resembled a writing tool. One participant mentioned, "*If I can hold the device as a marker, I will have more control while drawing*". Participants also reported that instead of buttons, touch-based interaction could be implemented. One participant shared his experience with Apple's Magic Mouse and said, "*I like the touch interactions and prefer to have only one button for click operation*". Three participants mentioned that the mouse could offer a pressure-sensitive body that can detect left and right click and trigger scroll function on tilting or bending the device. One participant compared the pressure sensitivity with a color brush and mentioned, "*During drawing, I can apply varying pressure to gradually increase the thickness of the line or modify the slope of the curved segment*". Participants also mentioned that the device must have

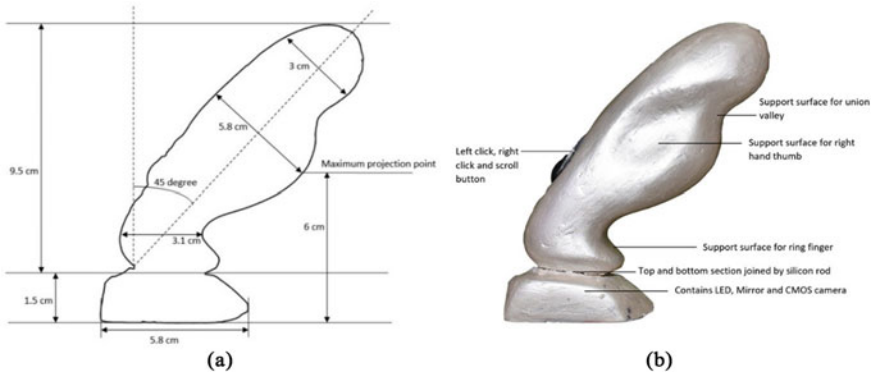

Fig. 2 (a) Cross-section side view of Prototype-1 (b) Side view of Prototype-1

the ability to stand vertically by itself to avoid picking up the device every time they need to use it. One participant reported, "*Unlike pen, the device should stand straight when I release my grip to do other tasks*". We studied and compared all shapes and ideas of clay mockups to generate a common design concept to create Prototype-1 (Fig. 2b).

4.2 The Iterative Process of Refinement

This subsection presents the design iterations and the rationales behind each modification, starting from Prototype-1, which was developed based on the proposed shapes and ideas with clay mockups. All the prototypes are developed by cutting and polishing Expanded PolyStyrene (EPS) sheets with a coating of acrylic wall putty over the EPS to make the outer surface hard and smooth.

Prototype-1. As shown in Fig. 2a, the device's height is 11 cm, where the top section of the mouse where the user holds the device is 9.5 cm tall, and the bottom section is of height 1.5 cm. This bottom section contains the complementary metal–oxide semiconductor (CMOS) sensor, light-emitting diode (LED), mirror, and the required circuit to build a working prototype. The device's body is inclined by making an angle 45° to the vertical axis for comfortable gripping. The height of the maximum projection point from the working surface is 6 cm. As shown in Fig. 2b, the top section of the mouse contains support surfaces for the thumb, ring finger, and union valley of thumb and index finger. The left-click, right-click, and scroll buttons are on the front side of the mouse. The top and bottom sections are connected via a flexible material (cylindrical silicon rod of diameter 1 cm). The flexible silicon rod allows users to exert pressure in any direction.

After developing Prototype-1, we conducted a think-aloud session to understand user experience. The same set of users were asked to use Prototype-1 for a limited period (10 min) and describe their experience while using the prototype. During this

time, we asked users to imagine if they are using this pointing device to move the cursor along a straight path (horizontal, vertical, and diagonal) and circular path and pretend to perform left-click, right-click and scroll operation.

We found that users with large hand sizes found the grip comfortable. Users with smaller hand sizes found the projected support surface for union valley to be larger than required. Users with medium and small hand sizes found the mouse uncomfortably tall. Properly holding the mouse by utilizing all the support surfaces leaves a gap between the wrist and work surface with a radial bend on the wrist, contributing to losing control during movement, non-uniform movement, and discomfort on the wrist. The flexible join between the top and bottom sections allowed users to make minor bends. However, we noticed an adverse effect of including this flexible join. As soon as the user reduces pressure on the device, the flexible material tries to retain its normal shape, contributing more towards non-uniform movement. On the contrary, participants enjoyed this addition of flexible material and reported several input interaction opportunities such as bending toward different directions and holding the bend on the joint. The majority of the participants with medium and large hand sizes used the join between the top and bottom sections to support the ring finger, especially while pushing the device towards the front.

Prototype-2. To minimize the user-reported drawbacks of Prototype-1, we developed a second prototype (Fig. 3a). The height of Prototype-2 is reduced to 11 cm, where the body of the device itself (without a bottom section of Prototype-1) will contain the CMOS sensor, LED, and Mirror along with the required circuit to make this a working prototype. For making the grip comfortable for a larger range of hand sizes, the size of the projected support surface for the union valley is decreased by 1.2 cm (5.8 - 4.6 cm), and the height of the maximum projection point from the working surface is reduced by 1.3 cm (6 - 4.7 cm). These values were calculated based on the difficulties experienced by the participants in the previous study for Prototype-1. For reducing the radial bend on the wrist, the mouse's body is inclined

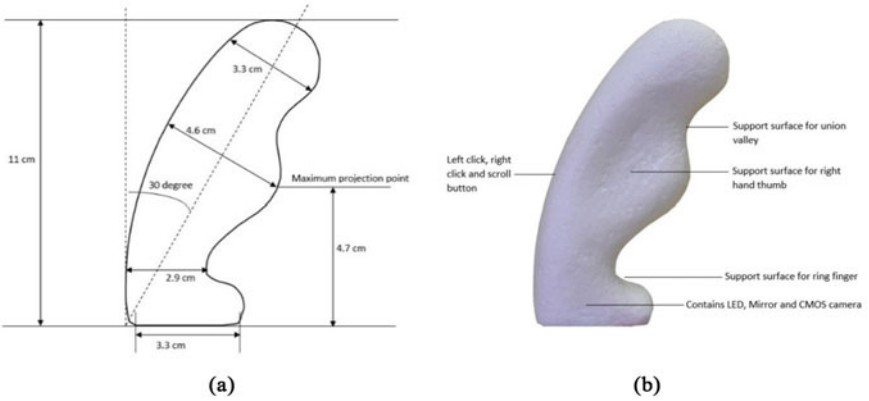

Fig. 3 (a) Cross-section side view of Prototype-2 (b) Side view of Prototype-2

by an angle of 30 degrees to the vertical axis. As shown in Fig. 3b, the positions of support surfaces, left-click, right-click, and scroll buttons are similar to the previous prototype. In this prototype, we used a silicon layer in the front of the device instead of adding a physical clickable button to resemble buttons that support both touch and click operations. We also added a silicon layer at the bottom surface to allow users to exert pressure and tilt the device in any direction. This silicon layer served as an alternative to Prototype-1's flexible joint without affecting the movement.

After developing Prototype-2, we again conducted a think-aloud session with the same group of participants to understand user experience. During the limited period of interaction (10 min), users were asked to imagine as if they were using this pointing device to move the cursor along a straight path (horizontal, vertical, and diagonal) and circular path and asked to perform one and two fingers tap, swipe and click. During this study, we explicitly mentioned to the participants not to relate the one or two fingers tap, swipe, and click to typical left-click, right-click and scroll operations. This allowed participants to focus on the device's shape and handgrip rather than interaction. Compared to the previous prototype, users with smaller and medium hand sizes found the projected support surface for union valley to be more comfortable. The height of Prototype-2 was also found to be comfortable by users with medium and large hand sizes. Participants with small hand sizes found the device height to be comfortable but wanted to use the support surface for both ring and little finger. Participants with medium and large hand sizes also preferred the support surface for the ring finger. They recommended the need for larger space for uncrowded placement of both ring and little fingers. Prototype-2 is not a working prototype, and it does not contain any circuit and battery inside the body, which reduced its weight as compared to the previous prototype. Due to reduced weight, the participants experienced unintentional shifts from the upright position during two-finger tap or click operations. This reduced weight also contributed to losing control over the device as it tends to move in any direction. All the participants liked the silicon-based bottom layer of Prototype-2 that allowed them to try out tilting or bend the device's bottom layer by exerting additional pressure. However, the use of a silicon-based bottom layer created added resistance while moving the device.

Prototype-3. To keep the pointing device stable in an upright position, weight needs to be added closer to the bottom of the mouse. The center of gravity of the mouse also needs to be shifted towards the front to keep it stable during the backward movement. The bottom contact surface of the device also needs to have less resistance. To achieve these goals, as shown in Fig. 4a, in Prototype-3, the height of the mouse is decreased by 1.5 cm (11–9.5 cm), whereas the body of the mouse will also contain a AAA size battery (weight approximately 6.7 gm) along with CMOS sensor, LED and the mirror along with required circuit. The body of the mouse is inclined by making an angle 25 degrees (instead of 30 in Prototype-2) to the vertical axis, and the excess portion above the union valley support surface is removed to shift the center of gravity towards the front. The total weight of the mouse is 39.8 gm, which resembles the weight of a typical wireless mouse.

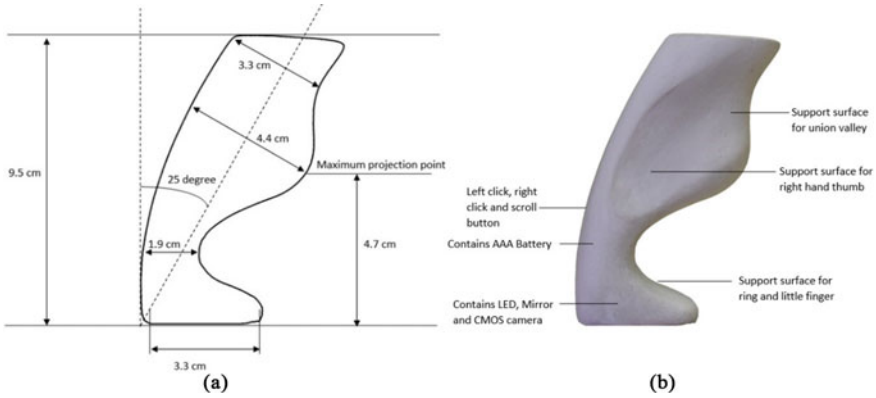

Fig. 4 (a) Cross-section side view of Prototype-3 (b) Side view of Prototype-3

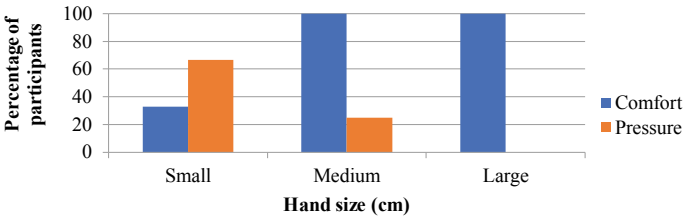

Fig. 5 Perceived comfort and pressure on the wrist with respect to three groups of hand sizes

As shown in Fig. 4b, the body of the mouse contains support surfaces for the thumb, union valley between thumb and index fingers, and larger space to rest (and support) the ring and little finger. Like Prototype-2, the provisions for left-click, right-click, and scroll buttons are kept in the front of the body that resembles buttons that support both touch and click operations. We also added a thin cloth on the bottom silicon layer to reduce friction and provide stable control while moving the prototype.

4.3 Study on Perceived Comfort and Pressure

We conducted this study with the same set of participants with an aim to understand the perceived comfort and pressure on the wrist while using Prototype-3. We provided a limited period of interaction (15 min), where users were again asked to imagine as if they are using this pointing device (Prototype-3) to move the cursor along a straight path (horizontal, vertical, and diagonal) and circular path. We also asked the participants to perform one and two fingers tap, swipe, and click. As shown in Fig. 5, all the participants with medium and large hand sizes reported comfortable gripping while operating with Prototype-3. The majority of these participants reported no

pressure on the wrist. However, the majority of the participants with smaller hand sizes reported discomfort and pressure on the wrist. The participants who reported pressure on the wrist had smaller hand widths which restricted them from fully utilizing the support surface for little and ring fingers.

The verbal feedback of the participants with smaller hand sizes indicates that the size of the final prototype is not yet very comfortable to them. One of them mentioned, "*the grip is comfortable to me, but it would have been more comfortable if the diameter of the cylindrical shape is reduced by a little*". We believe that the width of the maximum projection point (4.4 cm in Fig. 4a) contributes to the discomfort experienced by the participants with smaller hand sizes. However, all participants enjoyed using a vertical pointing device that allows the flexibility of tilting the device to interact. In the same context, one participant with medium hand size mentioned, "*it will be easier to draw curved lines with this mouse than using a traditional mouse*". Another participant reported, "*It feels like I am using a large eraser to control the cursor*". All the participants enjoyed using this vertical pointing device that enables user input through button click, touch and bending the bottom surface. One participant mentioned, "*I liked the way it works. It feels like a large joystick that can also move*". As the proposed pointing device allows users to keep their hands in a more ergonomically desired posture, we believe that it has the potential to reduce the risk of musculoskeletal disorder caused due to prolonged use of the typical computer mouse. However, estimation of pressure on muscle, fatigue, and their effect on reducing the risk of musculoskeletal disorders require further investigation through a longitudinal study.

5 Limitations and Future Scope

The initial design concept and the changes in each iteration of the prototype were governed by the feedback and suggestions of the participant group, which included students with different hand sizes. This limits the scope of fulfilling the complete requirement of any specific user group with a distinct range of hand sizes. Moreover, this work focuses only on right-handed users. This offers an opportunity for research on multiple user groups considering different ranges of hand sizes and dexterity. Enhancement of the affordance of the prototype and investigating the touch and click-based input with one or multiple fingers also require further research. Exploring the potential of bend gesture-based input for multimodal input interaction and comparison of the final prototype with other pointing devices may produce promising results.

6 Conclusion

This work proposes a design concept of a computer mouse that enables a comfortable right-handed grip on the device in a more ergonomically desired wrist and hand posture. We applied a participatory design approach where the first study was conducted to identify the shape of the pointing device that offers a comfortable right-handed grip. After two iterations driven by user feedback, we finalized Prototype-3 that maximizes user comfort and control on the device with reduced pressure on the wrist. We conducted another user study with ten participants belonging to three distinct ranges of hand sizes to evaluate perceived comfort and pressure on the wrist while using the final device concept (Prototype-3). We found that all the participants with medium and large hand sizes reported comfortable gripping, and the majority of them reported no pressure on the wrist. The participants with small hand sizes reported discomfort and pressure on the wrist, particularly the participants with smaller hand widths. All the participants enjoyed using the vertical pointing device that offers potential user input through button click, touch and bending the bottom surface.

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Ergonomic Risk Factors Among Eye Care specialists- A Study of Community Outreach Health Camps of Assam

Abhijit Kakati and Amarendra Kumar Das

Abstract Healthcare professionals are likely to face debilitating musculoskeletal disorders (MSDs) when screening their patients for any health-related abnormalities. This holds for most of the community outreach eye camps of rural Assam. Field studies at 17 health camps provided insights into the present scenario of eye care services and potential risk factors associated with specific routine procedures. A rapid upper limb assessment (RULA) worksheet, along with a modified Nordic Musculoskeletal Questionnaire (NMQ), was used for the study. Perceived discomfort level and occurrence after a health camp were measured using Borg's and Likert scales, respectively. Stick diagrams of postures adopted by the specialists during eye screening were prepared for RULA analysis. 170 observations corresponding to each screening procedure at the eye camps was used in the analysis. Objective refraction followed by indirect ophthalmoscopy, subjective refraction, and slit-lamp examination reported mean RULA scores of 6.87, 6, 5.77, and 5.09, respectively. The perceived discomfort level of the eye care experts ranged from 2 to 6.47, with knees being the least rated region and lower back the most. Job-related risk factors like performing the same task repeatedly, working for an extended period, awkward postures, insufficient breaks were reported by the respondents as contributors to musculoskeletal disorders while performing the routine procedures at the campsites. The study's findings contribute to understanding the physical discomforts that the eye care specialists face in the community outreach health camps. A high rate of musculoskeletal abnormalities was observed during the analysis that accounts for immediate ergonomic intervention.

Keywords Health camps · Eyecare · Ergonomics · Musculoskeletal disorder · RULA · NMQ

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1 Introduction

Work-related Musculoskeletal Disorders (WMSDs) are a common occurrence in diverse professionals worldwide. Performing tasks with a high force demand, long duration, frequent repetition, and tasks with sustained awkward postures [1, 2] are the common physical factors responsible for contributing to the high incidences of musculoskeletal disorders (MSDs) in the workplace. The eye care experts often have to maintain static postures involving their neck, wrist, and shoulder during the eye examination process. The prevalent physical MSD risk factors among eye care providers such as ophthalmologists and optometrists comprise repetition, long task periods, and frequent exposure to non-neutral postures like twisting, extending, bending the wrist, neck, etc. In a study, it was observed that the prevalence of musculoskeletal pain among eye care providers is considerably high when compared with family medicine physicians [3].

Rural areas lack adequate utilization of eye care services, mainly due to a lack of facilities and service providers [4]. Ergonomics is considered to be an essential factor in the healthcare diagnosis paradigm. Faults in ergonomics tend to develop MSDs and erroneous outcomes on the part of the healthcare providers in the diagnosis process. Community outreach health camps have remained an integral part of the rural population of Assam for access to eye care services. However, most eye camps lack basic facilities when compared to urban clinical settings [5]. A proper environment is essential in conducting the screening process, which, if not maintained, results in incorrect findings and escalates MSDs among the providers. Such settings are a challenging task to set in rural campsites. In community eye camps, hundreds of patients turn up in a single day, whereas the medical experts are very few. This is a huge challenge on the part of the eye care experts as screening all the patients require a larger time frame.

Considering the high incidences of WMSDs in eye care service delivery in the health camps, there is an urgent need for identifying the potential risk factors responsible for MSDs of the practicing eye care experts. This research attempts to capture the work-related musculoskeletal discomforts experienced by the eye care specialists while performing routine procedures in a health camp setting. The study also portrays the job factors responsible for contributing to WMSDs at the health camps.

2 Materials and Methods

2.1 Study Setting and Participants

The study was conducted in 17 rural health campsites of Assam, and the participants of the study are limited to only eye care experts (ophthalmologists and optometrists) having exposure to at least two years in serving at eye health camps. A total of 49 eye care experts working in different hospitals and eye clinics participated in the

Table 1 Demographic characteristics of the study population (n = 49)

Variables	Complete group (n = 49)	Male (n = 33)	Female (n = 16)
Age (years)			
20–30	27	17	10
31–40	16	12	4
41–50	6	4	2
Smoking (%)	63.26	84.84	18.75
Drinking (%)	75.51	70.27	68.75
Physical exercise/yoga (%)	77.55	75.75	81.25
Years of employment (Mean (SD))	6.5(4.2)	7.15(4.7)	6.3(4.1)
Years of Health camp experience (Mean(SD))	5.1(3.3)	5.6(3.7)	4.1(1.9)
No. of camps in a week (Mean(SD))	2.7(1.2)	2.8(1.2)	2.9(1.1)
Working hours/camp (Mean(SD))	8.7(0.8)	8.8(0.9)	8.3(0.6)
Interval of breaks if any (hours) (Mean(SD))	0.6(0.2)	0.5(0.1)	0.7(0.2)

study. 67.35% of the participants were male, and only 32.65% were female. Table 1 details the demographic characteristics of the participants of the study. The health camp setting was considered for the study because the work environment at the campsites is quite different from a hospital or a primary eye care center and comes as a challenge for the eye care specialist. We took permission to attend the health camp from the health camp organizing committee. The consent was taken two days prior to the health camp. The participants were informed of the aim and content of the study. We assured the participants of preserving their privacy regarding names and workplaces throughout the study.

2.2 Data Collection

A combination of different data collection methods was adopted for the study. This included direct observation at the health campsite and assessing postures of the eye care experts deployed at the campsites. Ergonomic assessment tool- Rapid upper limb assessment (RULA) [6], along with a modified Nordic Musculoskeletal Questionnaire (NMQ) [7], was used for the study.

Field study was done to gather insights into the present condition of eye care services and potential risk factors (repetition of a task, insufficient breaks, working in an uncomfortable position for long, and working fast due to increased patient

inflow) associated with specific routine procedures at the health camps. Information like average time spent in a health camp, the average number of patients screened for, standard procedures adapted in health camps for eye care service delivery, associated risk factors causing WMSDs, etc., was gathered from the eye care experts. The current study considers routine procedures like slit-lamp examination, indirect ophthalmoscopy, objective and subjective refraction. It is challenging for the experts to perform the routine functions in a campsite setting compared to a standard clinical setting (office setting/hospital setting).

Specific work postures during different examination procedures (slit-lamp examination, indirect ophthalmoscopy, objective and subjective refraction) were made into stick diagrams as photography and video were not allowed for privacy concerns. Due to the heavy inflow of patients at the health camps, making stick diagrams per person was unmanageable. Ten stick diagrams of each of the different procedures were drawn on-site at each health camp (resulted in forty stick diagrams per health camp). The eye care experts verified the stick diagrams at the end of the camps. They were able to identify accurately the stick diagrams associated with a specific procedure. This established the reliability of the stick diagrams made. The stick diagrams helped perform rapid upper limb assessment of the work postures adopted during the routine eye screening procedures.

A modified NMQ was used for studying the prevalence and analysis of MSDs among the study population. The questionnaire consisting of information related to the demographics, workload, occupational pain, and injury of the study population was distributed online. The questionnaire included an anatomical diagram of the human body, and the respondents were required to fill in their discomfort level at the appropriate location. The discomfort level scale was adapted from Borg's scale [8]. The scale is used to measure the perceived discomfort level of the eye care experts at the end of the health camp at different anatomical regions of the human body. Perceived discomfort level specific to a procedure adopted at the eye health camps could not be measured effectively using the modified questionnaire as different procedures are adopted in continuation while screening patients. However, the questionnaire successfully extracted information related to the overall discomfort level (on different anatomical regions) of the eye care experts at the end of the camp. In the modified NMQ, the frequency of occurrence of discomforts specific to a particular body region was also included. The respondents are to mark in the appropriate body region in the body map the frequency of discomfort experienced after the health camp. The options were included in a Likert scale ranging from Never (N), Rarely (R), Sometimes (S), Often (O), and Always (A). The participants were to write the appropriate letter corresponding to a particular option in the specific body region. The participants were made familiar with the questionnaire at the health camp itself. After guiding the participants on how to fill the questionnaire, it was circulated online. The participants were provided with a time frame of 5 days for submitting the responses to the questionnaire. Table 2 details the distribution of musculoskeletal symptoms in different anatomical regions of the body as reported by the eye care experts.

Table 2 Frequency distribution of WMSDs centered on routine procedures of eye screening at health camps (n = 49)

Anatomical region	Routine procedures of eye screening							
	Slit-lamp		Indirect ophthalmoscopy		Objective refraction		Subjective refraction	
	n	%	n	%	n	%	n	%
Neck	41	83.67	36	73.47	39	79.60	16	32.65
Shoulder	35	71.43	32	65.30	37	75.51	19	38.77
Elbow	5	10.20	3	6.12	7	14.28	6	12.24
Hand & Wrist	33	67.34	30	61.22	34	69.38	31	63.26
Upper back	37	75.51	29	59.18	32	65.30	30	61.22
Lower Back	35	71.43	33	67.34	38	77.55	32	65.30
Thighs	11	22.45	8	16.32	17	34.70	15	30.61
Knees	7	14.28	4	8.16	9	18.36	7	14.28
Ankle/Foot	16	32.65	12	24.49	14	28.57	11	22.44

3 Results

3.1 Sample Description

The demographic characteristics of the study population, which included ophthalmologists and optometrists, are presented in Table 1. Among the study population of 49, 33 (67.35%) were male participants, and the remaining 16 (32.65%) were female, respectively.

A majority of the study population (55.10%) belonged to the age group of (20–30) years, and only around 12.24% fitted in the age group of (41–50) years. About 63.26% of the respondents had a smoking habit, of which 84.84% were male and 18.75% were female, respectively. Drinking comprised around 75.51% of the study population (70.27% were male and 68.75% female). 77.55% of the respondents reported doing some sort of physical exercise regularly (Table 1). The range of employment of the participants was from 2–21 years (Mean ± SD = 6.5 ± 4.2 in years) with male respondents (Mean ± SD = 7.15 ± 4.7 in years) and female respondents (Mean ± SD = 6.3 ± 4.1 in years), respectively (Table 1). The range of health camp experience of the study population was from 2–17 years (Mean ± SD = 5.1 ± 3.3 in years) with male respondents (Mean ± SD = 5.6 ± 3.7 in years) and female respondents (Mean ± SD = 4.1 ± 1.9 in years), respectively. The mean of health camps performed per week as reported by the participants is 2.7 (SD = 1.2). Over 86% of the respondents dealt with 30–50 patients per health camp and spent an average time of 10–20 min per patient. The mean of the working hours/camp in

the range of is reported to be 8.7 (SD = 0.8) with a mean break of 0.6 h (SD = 0.2) (Table 1).

3.2 WMSDs According to Routine Procedures Performed in Eye Health Camps

The work-related musculoskeletal symptoms as reported by the respondents categorized based on the work activities are presented in Table 2. Of the 49 respondents participating in the study, 83.67% mentioned having neck pain during the slit-lamp procedure followed by upper back pain (75.51%), shoulder pain (71.43%), lower back pain (71.43%), and hand & wrist pain (67.34%). Elbows (10.20%), thighs (22.45%), knees (14.28%), and ankle/foot (32.65%) were the least affected regions throughout the slit-lamp procedure (Table 2).

About 73.47% of the eye care physicians complained of experiencing neck pain while conducting indirect ophthalmoscopy at the campsites. This was followed by lower back pain (67.34%), shoulder pain (65.30%), hand & wrist pain (61.22%), and upper back pain (59.18%). The regions least affected while performing indirect ophthalmoscopy were elbows (6.12%), thighs (16.32%), knees (8.16%), and ankle/foot (24.49%) (Table 2).

From Table 2, it is evident that while performing objective refraction of the eye, the number of respondents complaining of shoulder pain (75.51%), hand & wrist pain (69.38%), and lower back pain (77.55%) increased as compared to the previous two procedures. 79.60% of the eye care physicians complained of having neck pain and 65.30% upper-back pain. Elbows (14.28%), thighs (34.70%), knees (18.36%), and ankle/foot (28.57%) were the least affected regions throughout the slit-lamp procedure (Table 2). Though the thighs were reported to be one of the least affected regions, there is a significant increase of the respondents complaining of thigh pain when compared to their counterpart (slit-lamp (22.45%) and indirect ophthalmoscopy(16.32%)) (Table 2).

During slit-lamp, indirect ophthalmoscopy, and objective refraction, most respondents complained of experiencing neck and shoulder discomforts. However, as seen from Table 2, the neck (32.65%) and shoulder (38.77%) were reported as least affected during subjective refraction. The most affected regions as reported by the participants were the lower back (65.30%), followed by hand & wrist (63.26%), and upper back (61.22%). Very few respondents reported elbows (12.24%), thighs (30.61%), knees (14.28%), and ankle/foot (22.44%) as an affected region (Table 2).

Job-related risk factors like performing the same task repeatedly, working for an extended period in the same position, working in awkward postures, handling devices during eye screening, insufficient breaks were reported by the respondents as contributors to musculoskeletal disorders while performing the routine procedures at the campsites. The job factors mostly affected body regions like neck, upper and lower back, shoulder and wrist & hand of the eye care experts while performing

routine examinations at the campsite. The only consideration was during subjective refraction, where the neck and shoulder were affected significantly less (Table 2).

3.3 RULA Analysis of the Postures Adopted by the Eye Physicians While Performing Routine Eye Procedures

The RULA method was employed for ergonomic assessment of the eye care specialists performing specific tasks like slit-lamp examination, indirect ophthalmoscopy, objective refraction, and subjective refraction at the health camps. RULA employee assessment worksheet [9] was used for the study. It was not possible to do a RULA study on all patients turning up at the eye camps because of the high inflow of patients. Specific work postures during different examination procedures (slit-lamp examination, indirect ophthalmoscopy, objective and subjective refraction) were made into stick diagrams (see Fig. 1). Ten stick diagrams of each of the different procedures were drawn on-site at each health camp. This sums to 170 observations per procedure in the seventeen eye camps (forty observations are recorded through stick diagrams in each of the eye camps). The stick diagrams were analyzed using a RULA assessment worksheet to obtain each procedure's final RULA scores.

Table 3 lists the descriptive statistics of the RULA analysis of 170 observations per screening procedure. Outcomes from the assessment indicate that the eye physicians

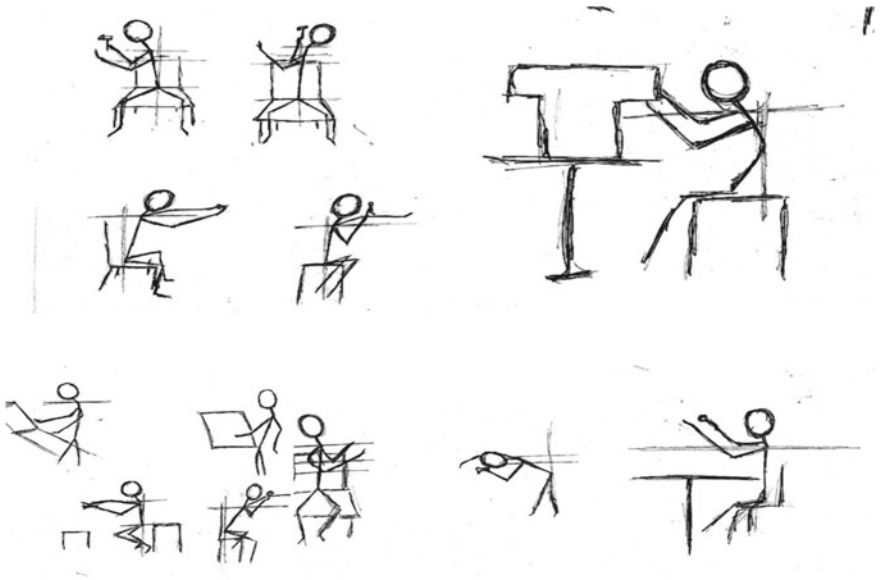

Fig. 1 Stick diagrams of postures adopted during routine screening procedures by the eye care experts

Table 3 Work posture analysis using RULA

Scores	Activity during eye screening			
	Slit lamp	Indirect ophthalmoscopy	Objective refraction	Subjective refraction
Mean postural scores (n = 170)				
Upper arm score	2.09	2	2.24	3
Lower arm score	2	2	3	2
Wrist score	2.22	3	3.83	4
Wrist twist score	1	1	1	1
Posture a score	3.08	3	4.66	5
Muscle use score	1	1	1	1
Force/Load score	0	0	0	0
Wrist and arm score	4.09	4	5.66	6
Neck score	3	4	3.69	2.16
Trunk score	3	5	3.87	2.78
Leg score	1	1	1	1
Posture B Score	4	7	6.13	3.4
Muscle use score	1	1	1	1
Force/Load score	0	0	0	0
Neck, trunk, Leg score	5	8	7.13	4.4
RULA Score (Mean ± SD)	**5.09 ± 0.28**	**6 ± 0**	**6.87 ± 0.33**	**5.77 ± 0.41**

Table 4 MSD risk level based on RULA score

Action level	RULA score	Level of MSD risk	Remarks
Level 1	1–2	Negligible risk	No action required
Level 2	3–4	Low risk	Change may be required
Level 3	5–6	Medium Risk	Further investigation is required, change soon
Level 4	6 +	Very high risk	Immediate change required

were exposed to a medium to a very high level of risk when performing such tasks, as mentioned before.

A mean RULA score of 5.09 is obtained while analyzing the postures of the eye physicians performing a slit-lamp examination and 5.77 during subjective refraction (Table 3). A mean score of 6 is obtained during analysis of indirect ophthalmoscopy posture, and a mean RULA score of 6.87 is found while analyzing for posture adapted during objective refraction (Table 3).

Table 4 shows the level of MSD risk associated with the particular RULA score of a specific task. Mapping Tables 3 and 4, it becomes clear that the eye physicians are at

medium to a very high-risk level of developing MSDs. A RULA score of 5.09 while performing a slit-lamp examination and 5.77 during subjective refraction and a score of 6 during indirect ophthalmoscopy signifies a medium risk of developing MSD, and further investigation and quick change of posture or activity are recommended. A mean RULA score of 6.87 while conducting objective refraction indicates a very high-risk level of developing MSD by the eye care physicians and suggests an immediate change in the procedure.

3.4 Frequency and Perceived Rate of Discomfort in Different Segments of the Body

The information related to the frequency of experiencing discomfort after a health camp were collected from the participants by employing a Likert scale. The responses obtained from the participants using the scale are shown in the form of a bar diagram (see Fig. 2). It is quite evident from Fig. 1 that the neck, shoulder, hand & wrist, upper back, and lower back regions of the body are most affected. The elbow, thighs, knees, and ankle/foot are the least affected of all. Some of the respondents complained of always experiencing discomforts in the neck, shoulder, hand & wrist, upper, and lower back regions of their bodies after attending an eye camp. A majority of the eye care experts also reported never experiencing discomfort in the body's elbow, thighs,

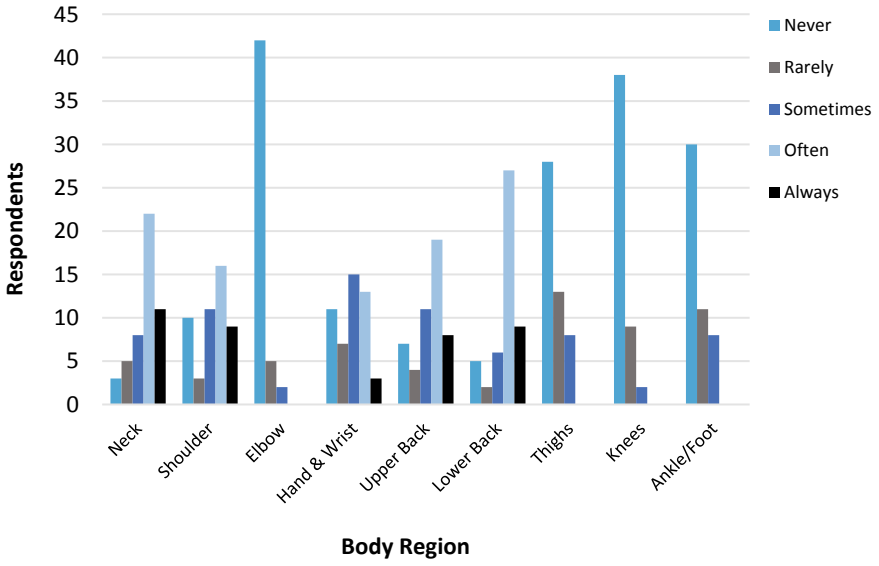

Fig. 2 Frequency of occurrence of perceived discomfort at different body segments

Table 5 Average perceived discomfort level of eye care experts based on Borg's scale

Anatomical region	Perceived discomfort level	
	No. of respondents/Percentage (%)	Borg's rating (Mean ± SD)
Neck	46/93.90	6.13±1.00
Shoulder	39/79.60	6.15±0.96
Elbow	7/14.30	2.7±0.75
Hand & Wrist	38/77.55	6.23±0.99
Upper Back	42/85.70	6.16±1.08
Lower Back	44/89.80	6.47±1.06
Thighs	21/42.85	3.04±0.67
Knees	11/22.45	2±0.63
Ankle/Foot	19/38.77	3.21±0.71

knees, and ankle/foot regions (see Fig. 2). The frequency of discomfort experienced at different segments of the body, as obtained from the Likert scale responses, does not correspond to a particular screening procedure individually. It takes into account all the processes that an eye care expert goes through in a single eye camp at rural sites.

The discomfort level scale was adapted from Borg's scale. The scale is used to measure the perceived discomfort level of the eye care experts at the end of the health camp at different anatomical regions of the human body. The average perceived discomfort level based on Borg's rating is detailed in Table 5.

The perceived discomfort level of the eye care experts ranges from 2 to 6.47 (based on Borg's scale), with the knees being the least rated region and lower back the most (Table 5). The neck, shoulders, hand & wrist, upper and lower back account for the most mean discomfort level (range between 6 and 7). A rating in the range of 6–7 on Borg's scale is considered strong to very strong discomfort experienced in the particular region. The perceived discomfort level in the remaining regions (knees, ankle/foot, thighs, and elbows) ranges between 2 and 4 (weak to somewhat strong on Borg's scale).

4 Discussion

To the best of our knowledge, this is the first kind of study conducted among eye care experts in health camp settings regarding the discomforts they face in different body segments. The research study extracted information regarding the WMSds encountered by the eye care experts when conducting routine screening procedures like slit-lamp examination, indirect ophthalmoscopy, and objective and subjective refraction at the eye camps. The environment of health camp settings is entirely

different from hospital and other clinical settings. The eye care experts encounter additional barriers in the health camp settings [5]. A high prevalence of WMSDs is reported in the study in most body segments by eye care experts. The neck, shoulder, hand & wrist, upper and lower back are found to be the most affected regions. The findings confirm that the prevalence of WMSDs among eye care experts is on the higher side. This is in line with a study conducted by Kitzmann et al. (2012). Job-related risk factors like performing the same task repeatedly, working for an extended period in the same position, working in awkward postures, handling devices during eye screening, insufficient breaks were reported by the respondents as contributors to musculoskeletal disorders while performing the routine procedures at the campsites.

The study provided insight into how stick diagrams of the procedural postures aid in conducting RULA analysis when there is no means of collecting data utilizing photographs and video on site. The stick diagrams were drawn on-site and later analyzed with the help of a RULA employee worksheet. A mean RULA score of 5.09 is obtained while analyzing the postures of the eye physicians performing a slit-lamp examination and 5.77 during subjective refraction (Table 3). A mean score of 6 is obtained during analysis of indirect ophthalmoscopy posture, and a mean RULA score of 6.87 is found while analyzing for posture adapted during objective refraction (Table 3). Though many studies on eye care experts were conducted to study the musculoskeletal symptoms, the present study provides procedure-wise mean RULA scores. This score helps to identify the severity of the working posture corresponding to a particular procedure in a health camp setting.

In the current study, the perceived discomfort level of the eye care experts ranged from 2 to 6.47 (based on Borg's scale), with the knees being the least rated region and lower back the most. The neck, shoulders, hand & wrist, upper and lower back account for the most mean discomfort level.

5 Conclusion

In conclusion, the research justified that prevalence of work-related musculoskeletal discomforts is quite common among the eye care experts working in outreach health camp settings. The study population included 49 eye care experts experienced in the community eye health camps of Assam. The study showed that musculoskeletal symptoms were more prominent in the neck, shoulder, upper back, lower back, and hand & wrists among the eye care physicians. The higher prevalence of musculoskeletal pain and discomforts in these regions was related to job factors like performing the same task repeatedly, working for an extended period in the same position, working in awkward postures, handling devices during eye screening, insufficient breaks, etc. The study's findings contribute to understanding the physical discomforts that the eye care specialists face in the community outreach health camps. The four routine eye screening procedures (slit-lamp examination, indirect ophthalmoscopy, objective refraction, and subjective refraction) at the health camp account for mean RULA scores of 5.09, 6, 6.87, and 5.77, respectively. The RULA scores are

associated with a medium to a very high level of MSD risk among eye care specialists. Perceived discomfort level was the highest in the lower back region and lowest in the knee. A high rate of musculoskeletal abnormalities was observed during the analysis that accounts for immediate ergonomic intervention.

6 Limitations

The research is concentrated on health camp settings, and so the results may not be generalizable in hospital/office settings as both the work environments are entirely different. Moreover, due to this limitation, a comparative study on the prevalence of MSDs in hospital/office settings and health camp settings is not possible. The exclusion of surgical procedures performed by the eye care physicians becomes another restriction of the study. As a result, musculoskeletal symptoms arising from performing surgeries like cataracts at the health camps could not be evaluated in this study.

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OSH Risk Perception of Safety Managers and Scope for Ergonomics Design Interventions in Floating Solar Photovoltaic Projects

Abhijit Sen and Sougata Karmakar

Abstract Utility-scale Floating Solar Photovoltaic (FSPV) projects are being installed in large numbers on water bodies across India. The installation and maintenance of these new projects are mostly carried out by unskilled temporary workers exposed to emerging OSH risks. Such occupational risks can lead to multifarious safety and health issues for the workers. These risks need to be addressed through appropriate risk mitigation measures such as design interventions. This study has been designed to understand the risk perception of safety managers regarding the types and degree of OSH risks faced by the FSPV workers to develop contextual design interventions**.** A risk perception questionnaire was developed, and responses of safety managers (n = 30) were obtained through a combination of in-person and virtual interviews. OSH risks in FSPV projects perceived by safety managers include fire, electrocution, solar radiation, heat stress, ergonomic risks, the threat from aquatic animals, hazardous materials, adverse weather conditions, skill gaps, etc. Safety managers are an important entity in the identification, design, and development of risk mitigation measures. The risk perception of safety managers will help as critical inputs for developing contextual design interventions for the FSPV workers. OSH risk mitigation is key in ensuring a safe and comfortable working environment for FSPV workers. The outcome of this study will assist industrial designers, ergonomists, safety & health professionals, and other industry stakeholders in designing and implementing appropriate design interventions from an ergonomics perspective.

Keywords Floating solar photovoltaics · Safety · Design · Safety managers

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1 Introduction

Clean and affordable energy is the aspiration of millions of people around the world. Several countries are adopting measures to generate energy from renewable sources to limit global warming and the emission of greenhouse gases (GHGs). India has taken the lead in this regard and plans to install 175 GW of renewable energy by 2022 and 450 GW by 2030 [1]. A significant part of this target consists of the installation of solar photovoltaic (PV) projects. Amongst many kinds of solar PV installations, floating solar PV projects (FSPV), which are deployed on water bodies, are gaining momentum because of their many benefits. The major advantages include huge availability of water bodies, better efficiency, land neutrality, decreased evaporation, use of existing power infrastructure, easier deployment as compared to ground-mounted/rooftop systems, avoidance of algae growth, and many more [2, 3]. Utility-scale FSPV projects are new work systems that involve significant manual work on both water and land. With a large number of FSPV projects coming up across India, contractual workers who are mostly from the unskilled category are being engaged for installation and maintenance. New work systems come with unknown and emerging risks. Unaddressed risks may lead to work-related musculoskeletal disorders, errors, lower productivity, lost man-days, psychosocial issues, accidents, and even fatalities [4]. Such occupational safety and health (OSH) risks need to be identified and addressed to avoid deleterious effects on the health of the workers. Some previous studies have identified OSH risks in the solar PV industry. They include heat [5], electrocution [6], ergonomic risks [7], fire [8], hazardous substances [9], and inclement weather & flora [10]. A comprehensive literature review on the emerging OSH risks in the FSPV sector has identified several occupational risk factors such as solar radiation, psychosocial factors, heat, electrocution, hazardous substances, adverse weather conditions, and ergonomic risks [11]. Using design as a means of risk mitigation, the review has identified several opportunities for design interventions such as workplace layout redesign, development of new tools, training modules, OSH standards, automation, ergonomic changes, and provision of job aids.

A field study on workers engaged in two FSPV projects in India revealed the existence of OSH factors such as ergonomic-related risks, lack of training, worker tool mismatch, and harsh environmental conditions. The identified scope for design interventions includes a change in work methods, design of scaffolds & walkways, tool modification, special shoes, solar panel & pontoon redesign, and development of context-specific PPE [12]. However, there is little or no research regarding risk perception and mitigation in the FSPV sector, with no studies in the Indian context.

By virtue of their experience, safety managers can be a good source of perceiving the risks associated with FSPV projects. Risk perceptions have been defined as "beliefs about potential harm or the possibility of a loss" which is subjective [13]. Risk perception involves understanding traits and the harshness of risk factors. This study is designed to understand the OSH risks from the perspective of safety managers to design mitigation measures and attempts to fill a knowledge gap existing in the FSPV sector. The research questions of this study were a) What are the OSH risks

(type & degree) perceived by the safety managers regarding workers engaged in FSPV projects? And b) What may be the various OSH risk mitigation measures that may be adopted from the perspective of safety managers?

This study aims to obtain OSH risk perception inputs from safety managers to develop risk mitigation measures from an ergonomics design perspective. The objectives of this study include (a) understanding the kinds of OSH risks faced by FSPV workers as perceived by safety managers, (b) perception of the type and degree of OSH risk and, (c) obtaining views of the safety managers regarding OSH risk mitigation measures.

2 Methodology

A questionnaire was constructed to obtain inputs from safety managers since a similar questionnaire was not found in any previous study in the FSPV sector. Questions and choices were framed so as to include holistic risk factors and interventions at all levels. The OSH risk factors used in the questionnaire were derived from previously published papers [11, 12]. The different types of interventions provided in the questionnaire were based on the choice of interventions collected during the pilot survey, which was carried out amongst the safety managers before the actual study. In addition, respondents were also allowed to suggest additional types of interventions. The reliability of the questionnaire was tested through a pilot survey ($n = 10$) using Cronbach's alpha [14]. The value of alpha was found to be above 0.70, which is acceptable [14]. The questionnaire consists of the following questions, namely, (a) general information such as organization, years of experience (especially in FSPV/solar PV projects), (b) perception of types of OSH risks faced by FSPV workers, (c) perception of the degree of each risk on a five-point risk perception scale based on severity, vulnerability, and frequency of exposure, (d) views of safety managers on risk mitigation measures/intervention choices provided in the questionnaire, (e) other aspects of concern regarding occupational safety and health of the workers.. Responses were obtained through a combination of in-person and virtual interviews. Thirty safety managers spread across different locations from ten organizations across India participated in the study. The participants are qualified safety professionals with formal education/training in occupational safety and health. The participant organizations include NHPC Ltd. (2), Tata Power Solar (3), POWERGRID (3), Tata Consulting Engineers Ltd. (4), Quant Solar (2), Sterling & Wilson (4), Cairn India (1), Bokaro Power Supply Corporation Ltd. (4), Engie Solar (2) and Damodar Valley Corporation (5). The figures in brackets indicate the number of safety managers who participated from each organization. The correlation between risk perception scores of participating organizations was also computed using Pearson Coefficient of Correlation [15] values.

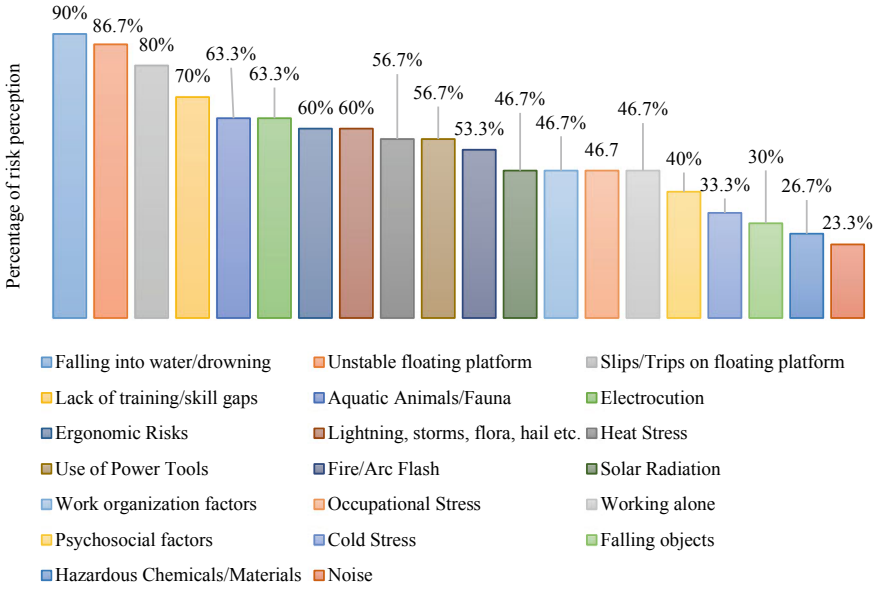

Fig. 1 Types of OSH risks perceived by safety managers and percentage of responses against each risk.

3 Results/Observations

The minimum work experience of the respondents was one year and the maximum was thirty-two years. Responses from participants with work experience of less than one year were not considered. Eight of the thirty respondents had direct working experience in FSPV projects.

3.1 OSH Risks in FSPV Projects

Figure 1 summarizes the percentage responses against each type of OSH risk faced by FSPV workers. Respondents from different organizations had the option to choose more than one type of OSH risk in accordance with their work experience while filling up the questionnaire. For example, 90% of the respondents opined that falling into water/drowning was a significant OSH risk for such workers. The OSH risk variables shown in Fig. 1 have been obtained from the questionnaire used in this study.

Table 1 Degree of perceived risk based on highest responses against each OSH risk

S. No	OSH risk	Degree of perceived risk	Percentage (%) of responses
1	Unstable floating platform	Very high	50
2	Slips and trips on the floating platform	Very high	46.42
3	Falling into water/drowning	Very high	44.82
4	Working alone	Very high/High	32*
5	Lack of training	Very high/High	29.62*
6	Psychosocial factors	Very high/High/Low	24*
7	Solar radiation	High	50
8	Electrocution	High	46.15
9	Fire/arc flash	High	42.30
10	Heat Stress	High/Medium	37.93*
11	Ergonomic risks	High	37.03
12	Use of power tools	High	37.03
13	Occupational stress	High	36
14	Lightning, storms, flora, hail, etc	High/Medium	34.61*
15	Cold Stress	Medium	46.15
16	Aquatic animals/fauna	Medium	34.61
17	Hazardous chemicals/materials	Medium	33.33
18	Work organization factors	Medium	28
19	Falling objects	Medium	29.62
20	Noise	Low	24

* Similar percentage responses for different degrees of OSH risk

3.2 Perception of the Degree of OSH Risks

Participants filled up a five-point Likert scale ranging from “very high risk” to “very low risk” against each OSH risk. The summary of the degree of risk perception of the respondents and the percentage of highest response against each OSH risk is shown in Table 1. For example, the participants ranked working alone as both very high & high risk.

In order to find out the correlation of risk perception scores of participating organizations, the Pearson Coefficient of Correlation value (r) was computed. A quantitative value was assigned to each degree of risk (very high risk = 5, high risk = 4, medium risk = 3, low risk = 2, and very low risk = 1). The scores against each OSH risk factor were used for any two given organizations to arrive at the "r" value. Likewise, all correlation values between participating organizations were calculated. The correlation values are summarized in Table 2.

Table 2 Comparison of pearson correlation coefficient values (r) based on risk perception scores between participating organizations

	ES	BPSCL	Cairn India	S&W	QS	TCE	PG	TPS	NHPC
DVC	0.33	- 0.12	-0.17	0.49	- 0.16	0.36	0.43	0.19	0.25
ES		0.05	0.28	0.22	0.15	0.12	0.03	0.15	0.49
BPSCL			0.03	-0.02	0.20	0.21	0.14	0.06	0.25
Cairn India				- 0.12	0.11	-0.25	- 0.23	- 0.45	0.38
S&W					0.34	0.33	0.51	0.33	0.43
QS						0.23	0.09	0.42	0.37
TCE							0.47	0.67	0.35
PG								0.40	0.15
TPS									0.20
NHPC									

S&W Sterling & Wilson, *DVC* Damodar Valley Corporation, *QS* Quant Solar, *BPSCL* Bokaro Power Supply Corporation, *TCE* Tata Consulting Engineers Ltd., *ES* Engie Solar, *PG* POWERGRID, *TPS* Tata Power Solar Ltd., *NHPC* National Hydroelectric Power Corporation Ltd

Interventions for OSH risk mitigation

The respondents provided their opinion on the preferred risk mitigation measures/interventions. A summary of the same is given in Table 3.

Other insights from the study

During the interviews, the participants expressed the following points of concern and suggestions in addition to the above:

Concerns:

- Lack of engineering controls for rigid structures
- Lack of periodical health check-ups, non-consideration of hygiene factors, and poor working conditions
- Lack of Standard Operating Procedures (SOPs)
- Non-consideration of water level, flow stability, and inclement weather before deployment of workers

Suggestions:

- Proper on the job training, ensuring medical fitness of the workers, proper HSE Policy, and availability of rescue teams/medical aids at the FSPV site
- Design of the floaters/pontoons and corrosion factor to be considered
- Ensuring earthing and grounding of the FSPV system
- Interventions for Manual Material Handling (MMH)
- Workers with hydrophobia to be screened. Only workers who can swim should be allowed to work on water. Provision of lifeboats to be ensured.
- Compliance with OSH standards and avoidance of night work

Table 3 Interventions as opined by respondents for OSH risk mitigation in descending order

S. No	Type of intervention	Responses (n = 30)	Percentage (%)
1	Safety training/behavioral change	29	96.7
2	Better supervision, oversight, and risk management	26	86.7
3	Design of personal protective equipment (PPE)	24	80
4	Design and display of safety signages	21	70
5	Planned maintenance keeping in mind weather conditions	20	66.7
6	Better Safety Climate/OSH culture	19	63.3
7	Occupational Safety & Health standards	18	60
8	Design of job aids	15	50
9	Improvement in work environment	14	46.7
10	Automation	14	46.7
11	Rest shelters	12	40
12	Redesign of workplace	11	36.7
13	Redesign of work-rest cycle/work organization	10	33.3
14	Lowering of loads/object weights	08	26.7
15	Better planning of the installation	01	3.3
16	Refreshment facilities	01	3.3
17	Better engineering controls	01	3.3
18	Environmental, health & safety (EHS)	01	3.3

- Provision for urinals and restrooms
- Proper payment of wages and statutory compliances
- Job safety analysis, mock drills, proper supervision, and use of insulated hand tools
- Design of PPE for protection against heat, solar radiation, glare, and humidity

4 Discussion

The top three OSH risks perceived by the safety managers include (a) falling into water/drowning (90%), (b) unstable floating platform (86.7%) and, (c) slips/trips on the floating platform (80%), as shown in Fig. 1. Falling into water/drowning, unstable floating platforms, and slips and trips on floating platforms (interrelated risks) were also identified in the "very high risk" (Table 1) category and need immediate attention. Risk factors such as working alone and skill gaps/lack of training have been identified as both "very high risk" and "high risk." Psychosocial factors have been categorized as very high, high, and low risk. The top three suggested interventions include (a) safety training/behavioral change, (b) better supervision, oversight, and

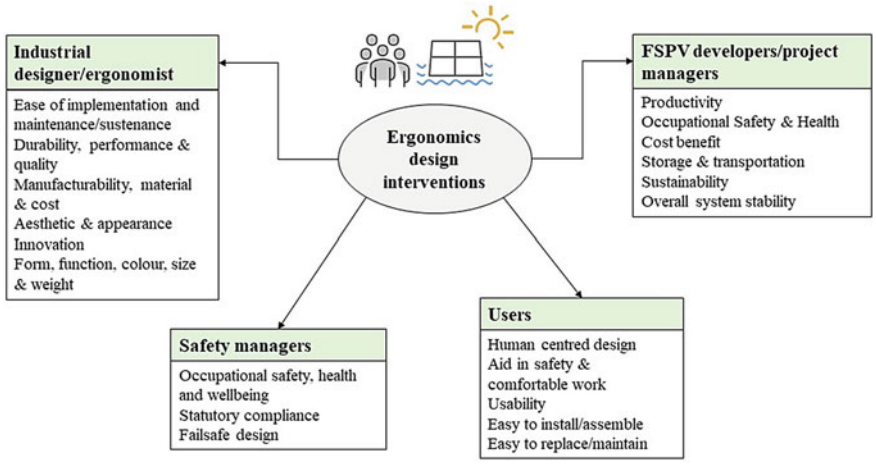

Fig. 2 Objectives of different stakeholders for implementing ergonomics design interventions in FSPV projects

risk management, and (c) design of PPE. The suggested interventions obtained from the present study are in consonance with the types of interventions identified in previous studies in the FSPV sector [11, 12].

It is evident from the present study that safety managers perceive a multitude of OSH risks in the installation and maintenance of FSPV projects in India. This study reveals many more types of additional risks apart from the risks already identified from existing literature (Sect. 1). This study also provides a diverse range of intervention measures that can be adopted by the concerned stakeholders. In addition, the insights gained from the study indicate that a system-driven approach will be required to neutralize many risks affecting the workers simultaneously. The prioritization of OSH risks further allows stakeholders such as industrial designers/ergonomists to decide, design, develop and target ergonomics design interventions towards specific problem areas. The correlation coefficient values (Table 2) indicate that there is mostly a positive correlation in the risk perception of safety managers of participating organizations indicating the convergence & agreement of views on the nature and degree of OSH risks and therefore, the immediate need for addressing them. The risk perception of the respondents may also be used as inputs for the development of tools and techniques for workplace safety. A focus on considering ergonomic design interventions is expected to resolve the contextual issues. A framework of objectives of different stakeholders while implementing design interventions is given in Fig. 2. This study was planned to find out the perception of OSH risks of safety managers. A limitation of this study is that the outcomes have not been corroborated with the risk perception of FSPV workers who are directly exposed to the OSH risks. Future work may be undertaken to compare risk perception outcomes of FSPV workers and safety managers. This will help in prioritizing and addressing the most critical OSH risk factors.

5 Conclusion

FSPV projects are new and emerging workplaces involving several mismatches between man, machine, and environment. Understanding the actual problem (s) being faced by the FSPV workers is a critical objective for any stakeholder interested in neutralizing sources of risk. The present study was designed to obtain the views of the safety managers so that the specific contextual problem areas can be identified and risk perception insights can be used as inputs in the design cycle. Future studies may explore the efficacy of specific design interventions considering stakeholder expectations with an objective to ensure safe and error-free work. This paper also attempts to attract focus towards the OSH issues in this emerging sector and provides a direction towards possible design solutions from different dimensions. The outcome of this study will assist industrial designers, ergonomists, safety & health professionals, and other renewable industry stakeholders in designing and implementing appropriate design interventions from an ergonomics perspective.

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Analyzing the Hand Grip Strength of Carpenters

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Abstract The hand grip strength is an important performing characteristic that can increase the efficiency of workers. The hand tools should be designed in such a manner that the workers can easily perform operations with sufficient grip on it. This study was conducted to measure and compare the grip strength of the carpenters of age between 19 and 60 years. The hand grip strength of 112 carpenters was determined in different postures. The carpenters were selected from the population of Jaipur district of Rajasthan (India) and all were male and native of Rajasthan. Grip strength of dominant hand of each participant was recorded with digital dynamometer. An indirect moderate correlation was observed between age and grip strength. The hand grip strength of first group (19–32 years) was observed more compared to the other two groups (33–46 and 47–60 years). The findings of such research studies may be useful for product designers while designing products targeting a particular age group.

Keywords Carpenter · Correlation · Grip strength · Hand tools

1 Introduction

The hand is regularly used in various daily operational and industrial activities. Many musculoskeletal disorders (MSDs) are caused because of this. Since grip strength is widely used for processing operations, it is essential to evaluate the grip strength to provide work capacity related information [1]. The carpenters usually manufacture, repair and install the wooden furniture, structures and fixtures. They perform various manual operations like planning, chiselling, cutting etc. using different carpentry tools like planes, chisels, saws etc. These activities are repetitive in nature and normally performed in awkward postures. Some frequently used carpentry hand

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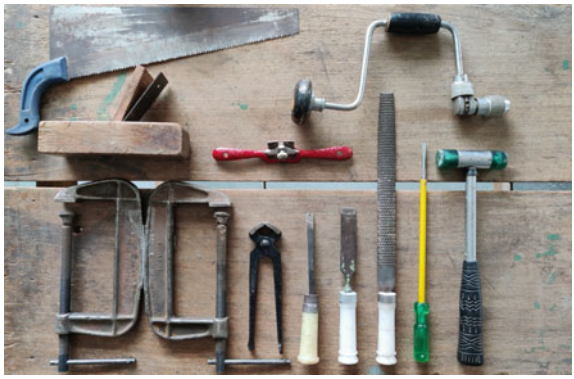

Fig. 1 Carpentry hand tools

tools are shown in Fig. 1. The handgrip strength is one of the major parameter for frequent hand movements in daily life activities and depends on both factors; physical and psychosocial factors. The handgrip study becomes more important for the advancement of simulations associated with hand [2].

The handgrip strength is generally used to identify the appropriateness of a professional for his profession [3]. The primary concerns while developing any work method or workstation, are the enhancement of the performance of tools and equipments and matching the work-abilities of the worker with the work requirements [4]. The work-ability of professionals and task requirements can be appropriately balanced. This can be done by applying principles of ergonomics with the help of accurate and latest technical information. Furthermore, productivity of the professionals and the system, their physical and mental fitness, work satisfaction, and safety can be optimized [5]. The profession is one of the important factors that influences hand grip strength. There are large numbers of profession who depends on hand grip ability to execute necessary tasks. The applicant sometimes requires passing handgrip strength test [6]. Researchers identified significant difference between handgrip strength among different professional groups. They concluded that the workers performing forceful actions with their hands in respective workplaces generally have high grip strength than others [7].

The continuously increased automation has decreased heavy manual actions in various workplaces. In small and medium scale enterprises (SMEs), there are still a big number of workers who perform heavy manual actions like lifting and carrying loads. The performance of handgrip strength can vary with different postures of operator's body. The work related MSDs may be caused because of a poorly ergonomically designed workplace in such an enterprise. The handgrip norms are really very helpful while designing a new product, a new tool, a new workstation etc. for safe physical work [8]. In case, if limits of strength of operators are repeatedly gone beyond the limit, MSDs may take place [9]. Researchers suggested that while designing any product or tool for strength, the normative data should be used. This normative data must be structured by use of the population that is strictly similar to the professionals being examined [10, 11]. Researchers observed that anthropometric

dimensions of hand, specifically width, length and circumference are directly associated to handgrip strength [12–14]. It was also investigated that handgrip strength of bigger hand is generally greater when compared with smaller hand [15, 16].

In this study, carpenters were categorized into three different groups according to their age. It was hypothesized that younger carpenters has higher handgrip strength than older carpenters and it decreases with increasing working hours, and there is moderate indirect correlation between handgrip strength and age of carpenters.

2 Methodology

2.1 Subject

This study was conducted in Jaipur, capital city of Rajasthan state of India. The subjects were randomly selected between 19 and 60 years old age carpenters. The subjects were then grouped in three different age groups (19–32 years, 33–46 years and 47–60 years). All carpenters were male and native of state of Rajasthan. The carpentry sites were visited and the different carpentry operations were closely studied before selecting them as participants.

2.2 Data Collection

To analyze the effect of age of carpenters on handgrip, their handgrip strength was measured. In this study, the handgrip of participants was recorded while performing task, a digital hand grip dynamometer was used. Each participant was verbally instructed and given demonstration before taking measurement. They were encouraged also so that they can give best handgrip strength value of their dominant hands. The test was conducted in standing position of participants keeping upper limb at neutral position as shown in Fig. 2. The data was collected on two different times of

Fig. 2 Experimental set-up

the day, one (N1) in beginning of the work and another (N2) post lunch time. The measurement of handgrip strength was recorded over three trials. Each carpenter held the dynamometer firmly about for 3 s followed by one minute relaxation between two successive tests. The best recorded value was then considered as handgrip strength value of each participant. Correlation analysis was conducted to predict the strength of the association of grip strength with age of carpenters.

3 Result and Discussion

In this study, total one hundred and twelve carpenters were selected for the investigation of handgrip strength. Among all the carpenters those were male, 98 were right hand dominant and rest 14 were left hand dominant.

Tables 1, 2 and 3 are summarizing handgrip strength measured for different age groups. A little consideration shows that the handgrip strength of first group of carpenters aged 19–32 years is significantly greater than that of carpenters in age groups 33–46 years and 47–60 years. The measurement N1 is the grip strength in beginning of the work and N2 is the grip strength post lunch time.

Table 1 Grip strength of carpenters (age group 19–32 years)

S. No	Age	Grip strength (kg)		S. No	Age	Grip strength (kg)	
		N1	N2			N1	N2
1	21	41.1	36.2	22	31	37.3	30.1
2	25	39	32.6	23	22	41.7	34.5
3	26	36.9	28.6	24	24	42.6	35
4	22	42	37.4	25	25	42.4	35.5
5	25	41.9	33.7	26	29	41.8	38
6	30	40.2	33.8	27	20	37.1	29.4
7	31	40.6	36.7	28	22	42.4	36.1
8	26	36.8	32.9	29	23	41.3	33.8
9	26	36.8	29.1	30	24	42	35.9
10	30	38.2	34	31	25	38.7	31
11	31	40.4	34.7	32	26	40.4	36.2
12	32	41.4	34.9	33	28	38.8	34.3
13	19	39.1	31.3	34	31	41.2	34.7
14	23	37.8	32.8	35	26	37.1	30.7
15	28	41.8	37.6	36	31	40.2	35.6
16	32	37.5	32.7	37	21	37.2	32.1
17	25	38.6	31.5	38	25	39.1	34.5
18	25	39	34.6	39	25	39.1	31.3
19	29	41.8	35.6	40	26	40.4	32.1
20	30	38.6	31.5	41	26	36.8	29.6
21	31	38.9	31.1	42	29	37.3	33.4

Table 2 Grip strength of carpenters (age group 33–46 years)

S. No	Age	Grip strength (kg)		S. No	Age	Grip strength (kg)	
		N1	N2			N1	N2
1	36	35.5	28.9	26	37	41.3	33.2
2	38	38.3	33.7	27	34	38.6	31.3
3	39	39.7	34.6	28	42	40.6	33.6
4	42	38.1	32.7	29	38	40.9	36
5	36	40.6	34.7	30	43	39.6	32
6	40	35.8	29.6	31	34	39.7	34.5
7	36	38.6	31.1	32	39	36.8	31.9
8	40	40.1	33.3	33	45	35.2	30.6
9	45	37	28.9	34	46	37.2	31.5
10	45	37.4	30.2	35	46	41.4	35.9
11	46	36.2	29	36	37	41.1	34.5
12	41	35.7	30.4	37	41	36.7	32.3
13	37	35.2	31	38	33	38	32.6
14	37	38.3	31.1	39	34	38.9	33.3
15	46	37.7	30	40	43	38.1	32.3
16	35	35.5	28.1	41	34	37.8	33.7
17	38	39.9	33.1	42	39	40.2	33.9
18	46	35.6	29	43	37	35.4	30.7
19	41	38.8	33.5	44	36	39.7	35.2
20	33	41	33.5	45	34	38.7	32
21	35	35.6	31.1	46	36	39.8	31.8
22	33	41.6	37.7	47	41	41.6	37.8
23	44	36	28.5	48	41	38.9	31.9
24	40	36.5	29.9	49	33	41.6	36.4
25	41	41	35	50	37	36.5	30.1

Table 3 Grip strength of carpenters (age group 47–60 years)

S. No	Age	Grip strength (kg)		S. No	Age	Grip strength (kg)	
		N1	N2			N1	N2
1	52	33.5	25.5	11	48	33.2	26.9
2	47	35.3	28.7	12	48	34.5	29.1
3	47	35	27.3	13	51	34.8	30.2
4	58	36.6	32	14	48	33.9	27.1
5	47	38.1	32.8	15	48	37.5	30.7
6	57	34.4	28	16	59	38.3	32.6
7	51	37.6	33	17	56	37.1	29.7
8	50	37.3	32.1	18	49	37.1	29.3
9	57	35.4	31.2	19	55	34.9	30
10	47	34.7	27.3	20	53	38.4	33.4

Table 4 is showing the difference in mean handgrip strength of all age group participants. There is a clear sign of reduction of handgrip strength of participants with increase in working time. It may be noted that this reduction in the handgrip strength can lead to various hand related MSDs with time.

The scatter plot shown in Fig. 3 represents the correlation of grip strength scores from 19 to 60 years old participants. The age of participants is on x-axis and handgrip strength is on the y-axis. The correlation between age and handgrip strength of carpenters is indicating that handgrip strength gradually decreases with increase in the age. The correlation shows that the age factor has significant correlation with handgrip strength. More specifically, the results obtained are showing a moderate negative relationship. This means that with the rise of age, handgrip strength will tend to decrease.

This study investigated handgrip strength of the population of Jaipur city of Rajasthan state of India. Such studies may be helpful for design of hand tools. It should be kept in view that the handgrip strengths of the two populations are always different. The handgrip strength depends on many factors, such as sex and hand anthropometry. The handgrip strength is observed moderately indirect related with the age of carpenters. This observation is consistent with the preceding research work [17].

Table 4 Comparison between grip strength in the beginning and post lunch

S. No	Age group	Mean grip strength (kg)	
		Mean N1	Mean N2
1	19–32 years	39.6	33.5
2	33–46 years	38.4	32.4
3	47–60 years	35.9	29.8

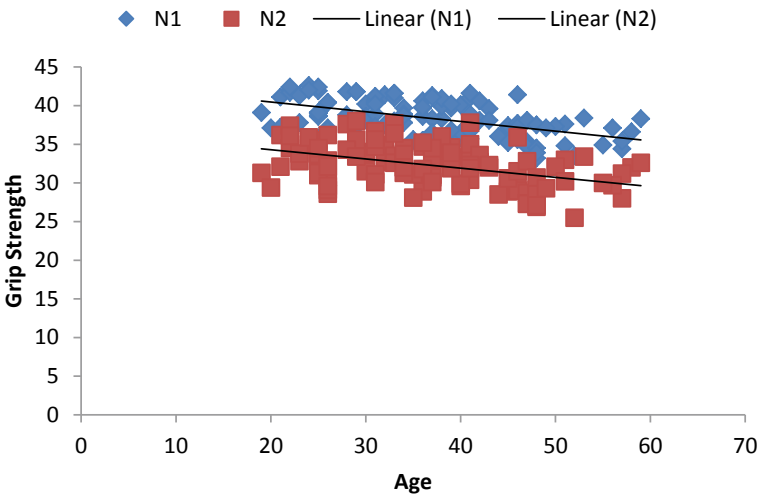

Fig. 3 Grip strength values of all participants of different age groups (19–60 years)

The results of this present study are depicted in the previous research findings [6, 10, 12, 14]. The results indicate significant differences in handgrip strength between the different age groups of carpenters. This is due to the fact that the handgrip strength is also correlated with the muscle mass and anthropometry [16, 18–20]. The effect of hand anthropometry factors on handgrip strength was not investigated due to short duration of study. It is also found that with the increasing working hours, the handgrip strength of people is decreasing. It may sometime lead to hand MSDs in workers. In order to improve the work efficiency of older carpenters and poor performers, the automatic tools may be a better option.

4 Conclusion

In ergonomics, the handgrip strength has been a classical performance characteristic of professionals that still needs more investigation. It is significantly affected with increasing age of people and their occupational working hours. Therefore, this study was focused on examination of the effect of these factors on handgrip strength of participants. This study compared the performance of carpenters of Jaipur city, capital of Rajasthan state of India. It was hypothesized that the handgrip strength is influenced with increase in age and working time of people. It was observed that the first group (age 19–32 years) performed with high handgrip as compared to other two groups (age 33–46 years and age 47–60 years). The age of carpenters and their handgrip strength was found correlated moderately indirect. After analyzing the measurements it is revealed that mean handgrip strength of people is decreasing with increase in working time. The most of Indian industries working hours are eight or more, that indicates, it may lead to hand MSDs in workers. The ergonomist and R&D team of industries should work together for better hand tool designs.

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Ergonomic Study on Farmers Involved with Cotton Harvesting in Haryana

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Abstract Cotton is one of the essential fibers and is the cash crop of India, which plays a vital role in the agricultural and industrial economy. Cotton farming does not only serve the textile industry but stimulates employment and the food sector as well. As a state, Haryana is one of the main producers of cotton. Harvesting of cotton is done manually and is a laborious task. The workers involved in harvesting activities usually have observed the development of work-related Musculoskeletal disorders (WRMSDs). This study aims to identify the WRMSDs and allergic reactions among the farmers involved in manual cotton-picking tasks. Direct observation, Nordic questionnaire and Interview was used to collect the data regarding WRMSDs and the allergy symptoms among the worker. Farmers of old age group 36–50 and > 51 were found to be more likely to report MSD symptoms in legs ($p < 0.05$), shoulder ($p < 0.05$) and lower back ($p < 0.05$). The same age group also reported symptoms of cough ($p < 0.001$) and skin allergy ($p < 0.05$), It was found that continuous bending, repeated hand motion and long working hours were the reasons for MSDs among the Farmers, and lack of usage of protective equipment and lack of knowledge about adverse effects of pesticide were found to because for the exposer to allergic symptoms.

Keywords Cotton farming · Musculoskeletal disorders · Repetitive tasks · Manual material handling · Harvesting

1 Introduction

Cotton is a Kharif crop whose harvesting requirements are different from other Kharif crops. It is one of the essential crops which provides raw material to the textile industry. The production of raw cotton in India is estimated to have reached 35.4 million bales in the year 2020 [1]. Cotton picking is a highly labor-intensive task. To prevent the lint from discoloration, the cotton must be picked at weekly

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intervals and thus requires a huge amount of human labor [2]. In India, Cotton is produced in three zones, the states of Haryana, Punjab, and Rajasthan come under the Northern zone, the states of Madhya Pradesh, Maharashtra, and Gujarat come under the Central Zone, and the states of Karnataka, Andhra Pradesh and Tamil Nadu come under the Southern zone [3].

Haryana is one of the main producers of cotton in India where cotton plucking is done manually to preserve the fiber characteristics [4]. Manual cotton picking is a very laborious and repetitive task. Cotton balls in India do not mature simultaneously and thus need to be picked in 2–3 rounds over the week or month. Balls that open later are considered of reduced quality. The farmers reported having bruises and cuts on their hands and toxication due to the use of pesticides from continuous working in the cotton field [3]. One study reported that manual cotton ball picking results in drudgery among farmers due to long attainment of bad posture and reported abrasion of fingers due to sharp points of dried bracts [5]. Drudgery load of harvesting activities such as removing stalks and stubbles was found highly associated with MSD, Repetitive strain, posture and Time load [5]. In another study, they found that cotton picking was most strenuous regarding physical parameters, where the women farmers reported fatigue, pain in different body parts, and headaches due to long hours of squatting and bending [6]. They also stated that picking cotton by hand creates high biomechanical stress on the shoulder and wrist of the farmer, and they need to frequently bend to pick up fallen cotton balls which put additional stress on the back muscles of the farmers [6]. Similar tasks are performed by vegetable flower picking workers where many researchers [7–9] have reported MSD in the lower back as a result of ergonomic risks such as repetitive muscle activity and awkward postures such as stooping and kneeling involved in their tasks. Some researchers have reported farmers experiencing illness significantly due to use of pesticides during inhalation, ingestion or dermal contact which results in acute problems such as eye redness, fatigue, cough [10]. Similar study shows problems like muscular symptoms, dizziness, headache, red/irritated eye are reported among farmers [11]. In another study, they found that skin reactions indicated as allergy due to cotton dust, where different symptoms have been observed on different person [12].

Though many studies have been done on the drudgery related issues in cotton harvesting [6, 9, 13, 14], the ergonomic aspect such as MSD related issues and ergonomic review of the tasks involved are very little explored. Thus, a focused, ergonomic study is needed to understand the different Work-related Musculoskeletal disorders involved in cotton harvesting. This study aims to find the WRMSDs and other irritants involved in cotton harvesting, thus aiding for future ergonomic interventions in the area.

2 Materials and Methods

The study was conducted in the Hisar district of Haryana. A total of 40 randomly selected farmers were considered for the study. The data collected was for one season as the harvesting is during December–January before frosting in 2020–21.

Three methods were adopted for data collection: direct observation, modified Nordic questionnaire and Interview focused on the other problems the cotton pickers faced and about the use of protective gears.

For statistical analysis, basic statistics were calculated, including percentages and totals. Prevalence of Symptoms of MSD and allergic reactions concerning demographic characteristics was found using the chi-square test for categorical variables such as age and gender. p values below 0.05 were considered statistically significant, and p values below 0.001 were considered statistically highly significant.

3 Results

3.1 Demographic Characteristics

Table 1 shows the reports of demographic characteristics, here it was seen that around 37.5% of the farmers are of the age group 25 and below, 15% of them were of the age category 26–35, 27.5% of them were of category 36–50, and 20% of them were of age 51 and above. It can also be seen that 50% of the farmers were male, and the remaining 50% were female.

3.2 WRMSD and Allergies Reported by the Cotton Pickers

Prevalence of MSD and allergies concerning demographic characteristics were found using the Chi-square test. Here the percentages of farmers who reported MSD in

Table 1 Demographic characteristics of the Farmers involved in the cotton picking task

Parameters	Categories	*N* (%)
Age	< 25	15 (37.5)
	26–35	06 (15.0)
	36–50	11 (27.5)
	> 51	08 (20.0)
Gender	Male	20 (50%)
	Female	20 (50%)

Table 2 Prevalence of symptoms of MSD reported by cotton pickers concerning to demographic characteristics ($n = 40$)

Parameters	Categories	WRMSD reported in different body parts							
		Arms		Legs		Shoulders		Lower back	
		N (%)	*P* value	*N* (%)	*P* value	*N* (%)	*P* value	*N* (%)	*P* value
Age	< 25	10 (66.7)		7 (46.7)		8 (53.3)		1 (6.7)	
	26–35	4 (66.7)		3 (50)		4 (66.7)		1 (16.7)	
	36–50	11(100)	0.053	10 (90)	0.013*	10 (91)	0.043*	11 (100)	0.00***
	> 51	8 (100)		8 (100)		8 (100)		8 (100)	
Gender	Male	15 (75)	0.212	13 (65)	0.49	12 (60)	0.028*	10 (50)	0.752
	Female	18 (90)		15 (75)		18 (90)		11 (55)	

where "*" indicates $p < 0.05$, and "**" indicates $p < 0.001$

different body regions were considered, p value below 0.05 was considered significant, and *p* value below 0.001 was considered highly significant. From Table 2, it was found that the MSD symptom in legs, shoulders and lower back were significantly higher among the farmers of age 36–50 and of age > 51, with 90 and 100% reports of MSD symptoms in legs under the age categories of 36–50 and > 51 ($p < 0.05$), 91 and 100% of the farmers reported MSD symptoms in Shoulders under age category of 36–50 and > 51 ($p < 0.05$) and all the farmers reported MSD symptoms in lower back under age category of 36–50 and > 51 ($p < 0.001$). This report also found that the MSD symptoms reported in shoulder were significantly higher among the females, with 90% reports ($p < 0.05$).

From Table 3, it was found that the allergic symptoms of Cough ($p < 0.001$) were significantly higher among the age group 36–50 with 100% report, followed by age group > 51 with 87.5% reports and age group 26–35 with 83.3% reports of cough symptoms. In addition, symptoms of fever and red-eye were found to be significantly high among the age group 26–35 with 83.3% reports ($p < 0.05$) and the symptoms of skin allergy was significant among the age groups 36–50 with 72.7% reports ($p < 0.05$). No significant changes in the occurrence of allergic symptoms were found in gender categories.

Table 4 shows the use of different protective equipment by the different categories of age groups, it was found that all of them used some kind of cloth for the protection, while mask and gloves were mostly used by the farmers of age more then 51.

Table 3 Prevalence of symptoms of allergic reactions experienced by the cotton pickers ($n = 40$)

		Allergic reactions experienced by the cotton pickers									
		cough		sneeze		fever		Red eye		Skin allergy	
	Categories	*N* (%)	*P* value	*N* (%)	*P* value	*N* (%)	*p* value	*N* (%)	*P* value	*N* (%)	*P* value
Age	< 25	3 (20)		5 (33.3)		4 (26.7)		2 (13.3)		1 (6.7)	
	26–35	5 (83.3)		5 (83.3)		5 (83.3)		5 (83.3)		3 (50)	
	36–50	11(100)	0.00**	4 (36.4)	0.135	2 (18.2)	0.022*	6 (54.4)	0.012*	8 (72.7)	0.004*
	> 51	7(87.5)		5 (62.5)		5 (62.5)		5 (62.5)		5 (62.5)	
Gender	Male	12 (60)	0.5	8 (40)	0.342	8 (40)	1	9 (45)	1	8 (40)	0.749
	Female	14 (70)		11 (55)		8 (40)		9 (45)		9 (45)	

Where "*" indicates $p < 0.05$, and "**" indicates $p < 0.001$

Table 4 Use of protective equipment ($n = 40$)

Age	Mask *n* (%)	Gloves *n* (%)	Cloth *n* (%)
< 25	0 (0)	2 (13.3)	40 (100)
26–35	2 (33.3)	2 (33.3)	40 (100)
36–50	7 (63.63)	6 (54.5)	40 (100)
> 51	8 (100)	6 (75)	40 (100)

4 Discussion

In the era where technology has provided solutions to an extent where any activities can be performed in comfortable condition and still manual cotton picking is practiced and considered an essential and necessary method as it produces fibers with better quality than those produced by other machine used methods such as picker and stripper harvesting systems [15]. From this research, we have observed that the problems of MSDs in legs, shoulders and lower back were highly reported by the age groups 36 −50 and > 51; this is the result of continuous bending and repeated actions of hands while manually removing the cotton balls. This finding goes in line with many other researches done in similar work environments and tasks such as in other agricultural practices like in uprooting job of rice cultivation [16] similar findings were also found in the research on Landscaping work [17] and research on flower farm workers in Kenya [18], they all reported similar reasons such as older age, working for long hours and multiple times a week, and other tasks with repetitive motions for the development of WRMSD among the Farmers [16–18].

Our research found that the symptoms of allergic reactions such as cough and skin allergy were highly prevalent among the older age groups 36–50 and > 51, while the symptoms such as fever and red-eye were highly prevalent among the younger age group 26–35. The report of usage of protective equipment shows that the younger age groups < 25 and 26–35 are less likely to use the protective equipment such as masks and gloves, whereas those of older age groups 36–50 and > 51 who have higher experience of working in the field are more likely to wear the required protective gears. This negligence of not using protective equipment could be why the younger age groups show fever and red eyes symptoms. Similar findings of the effects of non-usage of protective gears were seen in other research, such as in the research done among Thai agriculture Farmers have reported fever and red eye along with other adverse health conditions due to the use of pesticides and other chemicals [19]. Other researches on the use of Protective equipment [20, 21] have found that Personal protective equipment can largely reduce the health risk of the Farmers from adverse effects of pesticides. They have also suggested educating and training the Farmers regarding using protective equipment for their better health.

The limitations of this study are that a complete study on the protective equipment's and its effectiveness is required to fully understand the adverse effects on the health of the Farmers. Also, more data need to be gathered from the other cotton field sites, which will improve the effectiveness of this study.

5 Conclusion

The Farmers involved in manual cotton-picking activities are at significant threat of MSDs due to direct ergonomic risks involved in the tasks such as repetitive bending, repetitive hand motions, long working hours and old age. Ergonomic intervention is needed in this area to effectively aid the manual tasks of cotton picking and reduce the ergonomic risk involved. The Farmers were also prone to allergies due to chemicals and pesticides usage, the unexperienced Farmers were found to more exposed to these adverse effects of pesticides as they avoided the use of protective equipment, proper training and education for the Farmers regarding the effects of working in such condition and health benefits of usage of protective equipment is required. This study will provide the base information of the current conditions among the manual cotton pickers and aid in future ergonomic interventions.

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Assistive Devices Applicable for Inclusive Design in Higher Educational Institutes in India: A Systematic Review

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Abstract According to WHO, 15% of the world population has a disability. Achieving universal education for everyone and creating inclusive infrastructure is a part of the Sustainable Development Goal for 2030. Considering the feasibility of implementing the design and technological interventions for developing inclusive infrastructural facilities in higher educational institutes (HEIs), the current review focuses on HEIs in India. In developed countries, relevant research work is in full swing, and thus, design and technological intervention are being implemented in their HEIs. In developing countries, research has been rarely reported in this context. Moreover, data on assistive devices and human factor issues for making the HEIs universally accessible are seldom available. Hence, the present research aims to study existing assistive devices that HEIs could adopt for inclusive design for making Persons with Disabilities (PwDs) an integral part of the system. The literature search was conducted using Scopus and Web of Science databases to shortlist papers using suitable keywords and combinations while following the PRISMA framework. The collected literature was segregated under types of disabilities, difficulties faced by PwDs in HEIs, assistive devices for various limitations, application of assistive devices in the domain of services associated with education in HEIs. Further, primary research on the status of inclusive design should be taken forward, as there is a gap in research on the state of the art of inclusivity in HEI in India. Reported research would serve as the database on assistive devices for researchers working in the field of inclusivity, with particular emphasis on HEIs.

Keywords Specially-abled · Teaching and learning · Campus space · Person with disability · Architecture · Assistive technology

1 Introduction

According to WHO, 15% of the world population is disabled [1]. In India, the figures show 2.21% of the overall population to be disabled [2]. The conservative numbers

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of the disabled Indian population are due to contrasting health standards, awareness, knowledge, and medical diagnosis, and recognition of disabilities compared to other countries [3].

The Sustainable Development Goals (SDG) 2030 from United Nations Development Program states in SDG 4 to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." Further, the document expresses the need for equal access to quality technical, vocational, and tertiary education, including university education. To achieve this endeavor, it is an urgent requirement for building and upgrading educational institutions to turn them into an inclusive learning environment for all [4].

Following a similar approach, the Rights of Persons with Disabilities (RPWDs) Act 2016, Chapter III Education, point 16, calls for making educational campuses accessible for all and providing adequate accommodation and support that maximizes academic and social development. This is consistent with the goal of an inclusive environment. RPWD defines a person with a disability as "a person with long term physical, mental, intellectual or sensory impairment which, in interaction with barriers, hinders their full and effective participation in society equally, with others" [5].

International Classification of Functioning, Disability, and Health (ICF) uses a biopsychosocial model to define disability. The following diagram (see Fig. 1) shows a depiction of the model of disability.

The diagram shows that disability and functioning are a result of interaction between health conditions and contextual factors. It further exemplifies contextual factors as social attitudes, architectural characteristics, legal and social structures, terrain, and climate. The three levels of human functioning are; at body or body part level, at the whole person level, and the whole person in a social context level. Unable to function at one or more of these levels is disability: impairment, activity limitation, and participation restriction [6].

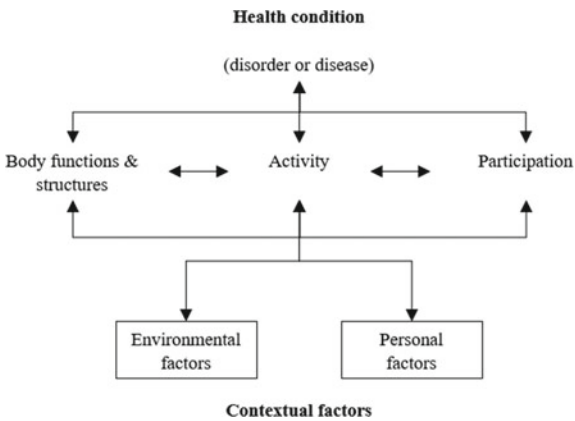

Fig. 1 Model of disability, ICF [6]

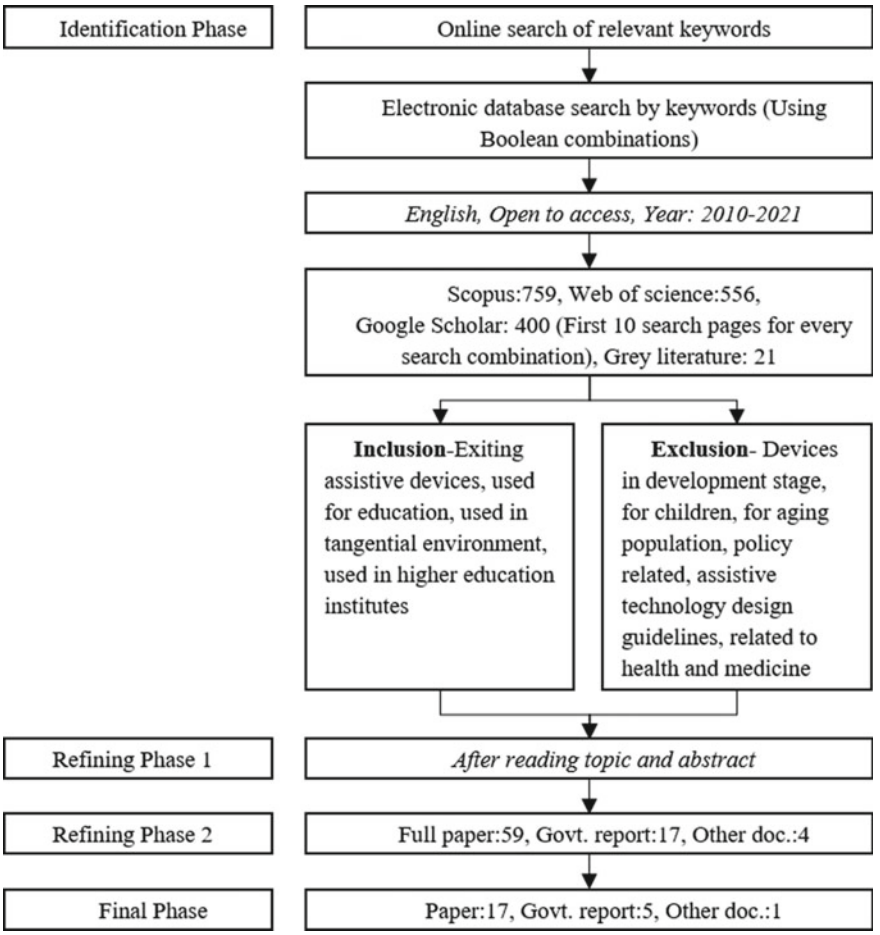

Fig. 2 PRISMA framework followed for paper selection

Ahmad [7], in his study, advocates for the requirement of research in developing countries, as a majority of papers on inclusive education are from developed countries. Although limited, the research in developing countries highlights the issues faced in implementing inclusivity in educational system. In these countries, people with disabilities face exclusion from education because of lacking facilities in institutions. Providing them with technology integration, making curriculum, and performing of task accessible will create an inclusive environment. This will improve their functioning and make formerly seemingly unachievable outcomes achievable. In their paper, Yadav et al. [8] stress on the need for research on the factors that affect inclusivity in educational institutes. These factors include campus management, stakeholders in campus, availability of assistive devices (ADs) or technology, built environment, social environment, and financial factors.

Table 1 Application of universal design in education [10]

Domain	Application
In instruction	Class climate, *Interaction, Physical environments and products, Delivery methods, Information resources and technology, Feedback,* Assessment, Accommodation
In services	Planning, policies, and evaluation, *Physical environments and products,* Staff, *Information resources and technology,* Events
In information technology	Procurement and development policies, Physical environments and products, Information, *Input and control, Output, Manipulations, Safety, Compatibility with assistive technology*
In physical spaces	Planning, policies, and evaluation, Appearance, *Entrances and routes of travel, Fixtures and furniture, Information resources and technology, Safety,* Accommodation

McNicholl et al. [9], in their study, provide evidence on how the use of ADs in higher education institutes can positively impact the participation and engagement of a person with a disability in an academic scenario. There are different areas in an educational institute where principles of universal design can be applied to make the institute inclusive in nature. A summary of how universal design concepts can be applied in different aspects of education is presented below in Table 1 [10].

Although there are many ways to apply universal design, to limit this paper's scope, it is mainly focused on reviewing the state of the art literature on ADs that are used in accessing physical spaces and facilitating education with special emphasis to HEIs. The systematic review of existing devices includes devices used in India and all over the world.

2 Review Methodology

A literature search was conducted using an electronic database of Scopus, Web of Science, and Google Scholar. Different combinations of keywords related to vision impairment and low vision, deaf and hard of hearing, mobility impairment, upper-limb impairment were searched in combination with assistive devices.

The above diagram (see Fig. 2) shows the PRISMA framework followed for this research. The search on the electronic database was done for the papers published after 2010; as the technology is rapidly changing, the data of devices being used will be up to date. The refining phase one, where the papers and grey literature were selected on the basis of topic name and abstract using inclusion and exclusion criterion, resulted in 80 documents. All the relevant articles and documents were downloaded and read. For further refining, papers were organized in an excel file and categorized on the basis of type of disability. Grey literature was compiled by accessing national and international organizations' websites that provided any information regarding demographics, disability, ADs, or related policies.

3 Assistive Devices (ADs)

Assistive products are defined by WHO as devices, equipment, software, or the instrument used externally that help people to become enabled and achieve freedom by bettering their functioning. This improves their overall quality of life. They provide an opportunity for people to take part in education and lead a professional and civic life. This leads to an endeavor of health, productivity, dignity, and independence [11].

3.1 Activities in Higher Education Institute

On the basis of activities done by stakeholders with disabilities, the requirement of assistive aides is listed below in Table 2. Existing assistive ADs are compiled in relation to the use for disabled people.

Documents by WHO and UN deliver a brief list of ADs that people with disabilities commonly use. They are items essential for the activities of daily life [12–15]. They also include ADs that are being used by infants, children, and aging person. Following is comprehensive data of the ADs that are being used to improve or aid the functioning of stakeholders with disabilities in higher educational institutes or other similar scenarios. Data is categorized based on types of disability.

3.2 Based on the Type of Disabilities

Visually impaired/Low vision The ADs that are being used by vision impaired stakeholders are depicted in Table 3 [16–23].

Hearing-impaired/Deaf and Hard on hearing ADs used by stakeholders with issues in hearing are provided in Table 4 [22–24].

Locomotor disabilities Stakeholders with motor impairment and upper-limb impairment fall under this category; Table 5 gives a list of assistive aides that they use [22, 23, 25].

3.3 Exploration of ADs from the Patent Database

Google patents was searched using appropriate keywords for preparing the list of existing ADs related to lower limb impairments (Tables 6 and 7) [26].

Table 2 Requirement of assistive aide based on activity

Level	Activity	Visually impaired/low vision	Deaf/hard of hearing	Mobility impairment	Upper-limb impairment
Navigation	Going from one building to another	AD	NA	AD	NA
	Commuting pathway	AD	NA	AD	NA
	Using signage	AD	NA	NA	NA
	Commuting to different rooms within a building	AD	NA	AD	NA
	Commuting to different floor	Tactile Lift Buttons	NA	Lift	Lift button access
	To maneuver inside a room	AD	NA	Space requirement	NA
Learning/communication	Lectures, discussions (verbal)	NA	AD	NA	NA
	Lectures, discussions (visual)	AD	NA	NA	NA
	Library (searching study material) Manually	AD	NA	Assistance in reaching racks	AD
	Searching study material (online-written)	AD	NA	NA	AD
	Searching study material (online-audio visual)	AD	AD	NA	NA

Note AD Assistive devices required, *NA* No assistance

4 Discussion

The systematic review on the impact of assistive technology use on students with disabilities in higher education synthesizes the results by reporting that ADs psychologically improve students' academic engagement. They positively affect the participation of students socially. However, it is noted that if the ADs are not used effectively (e.g., resulting from inadequate training), they can hinder the educational engagement. Yadav et al. [8] highlighted that adequate use of ADs reflects on psychological well-being and social and academic engagement of students with disabilities in the

Table 3 Assistive devices for vision-impaired stakeholders

Use	Assistive devices/system
Navigation	*Path guidance applications and systems* NavCog3, WayFindr, BeMyEyes, TapTapSee, iDentifi, SeeingAI, BeSpecular, Soundscape, BlindSquare, Lazarillo, Intersection Explorer, Lazzus, Arianna Navigatio, NaviLens, Sunu, OrCam, Blaid, eSight, iBionics
	Navigation system and devices Maptic, Microsoft Soundscape, SmartCane, WeWalk, Horus, Ray Electronic Mobility Aid, UltraCane, BlindSquare, Envision Glasses, Eye See, Nearby Explorer, Seeing Eye GPS, PathVu Navigation, Step-hear, InterSection Explorer, LAZARILLO APP, Lazzus APP, Sunu Band, Ariadne GPS, Aira, Be My Eyes, BrainPort
	Assistive glasses Google Glass, eSight, OrCam, Enchroma, Intoer, BrainPort V100, The Voice (To see pictures and images), Brainport Vision (To perceive and identify objects), iGlasses (Translate ultrasound information in tactile outputs), K-sonar (To translate echoes in sounds for navigating and scanning objects)
	App based solutions Seeing AI by Microsoft (Seeing AI), LookTel by IPPLEX (Money reader), VizWiz by ROCHCI (Image snapped and a query is shared online, which is replied by volunteer Web Worker, email, or Twitter.)
Learning/communication	*App based solutions* SayText by Norfello Oy (Reads text in an image), KNFB Reader (To read written documents. To), Prizmo 3 (To scan and read documents) *Specific to library* Braille books, audio books, Screen magnification software, Screen reading software, Scanning and reading appliance (SARA), Braille Embossers, Digital voice recorder, Large printer keyboards, Accessible website, e-resources, Study rooms Talking Calculator, Voice Recorder/CD player, Braille Printer/Embosser, Magnifying Glasses, Tactile Image Enhancer, Braille Translator, Voice recognition Software, Optical Character Recognition (OCR) software and a Speech Synthesizer, Large Print Book and Digital Talking Book, Optacon (To read printed material that has not been transcribed into Braille)
Miscellaneous	MusicEye (To provide visual information through a musical auditory experience.), Voice Over and Talking Tap Twice (TTT) (To make the smartphone accessible to visually impaired people)

higher education environment. They emphasized the need for the institute authorities to be conscious about the up-to-date ADs and how updating devices will best influence the disabled students' AD needs.

Dhara [22], based their study on the West Bengal region's universities in India, reported that the libraries considered in their study lacked resources for disabled stakeholders i.e., data was not available in the desired format, and adequate assistive aides were lacking, and the staff members lacked resources (not well trained to help).

Table 4 Assistive devices for hearing impaired stakeholders

Use	Assistive devices/system
Navigation	Flashing Ring Amplifiers, Visual and Tactile Alerting Devices, Baby Cry Signaler, Carbon Monoxide Detector, Smoke Alarm Signaler, Telephone Signaler, Wake-up Alarm Signaler, Weather Alert, Vibes Bed Shaker Alert Device, Alarming devices/signal systems
Learning/communication	The Deaf Messaging Service (DMS), Telephones Compatible with Hearing Aide *Specific to library* Assistive listening devices (ALDs), Augmentative and Alternative Communication (AAC), TDD/TTY (Teletypewriter) for outgoing telephone calls, Portable speech synthesizer, Assistive listening system, Closed-captioned decoders, Hearing aids/Cochlear implants, Televisions with built-in close captioning

Table 5 Assistive devices for locomotor impaired stakeholders

Use	Assistive devices/system
Learning	Madentec Tracker, Softype, Physical access (Parking and Accessible Pathway, Entrance, Internal Circulation, Accessible Furniture, Toilet, Signage, Emergency Evacuation) Prosthetic and Orthotic devices, Simple/Electric Wheel Chairs, Walking frames/Rollators, Adaptive furniture, Adaptive keyboards (e.g. Muppet Learning Keys, Power Pad, Unicorn Board, Touch Windows), Speech-input devices (e.g. Voice Master), Cursor-control devices (e.g. Adaptive Firmware Card, Multi-Switch Adapter Box), Any other (Television/Projection)/Tricycle, Cervical Collar
Learning/communication	Environmental control system, Writing orthosis, Forearm support, Trackball mouse, Joystick mouse, Head control device for a computer, Sip- and puff-control for computer, Mouse with external click, Special keyboard, Type support, Mouthstick, Touchscreen, Document holder, Page turner, Speech recognition software, Onscreen keyboard

It was opined that disabled students could not benefit from the current technological revolution. They suggested the requirement of retrofitting existing facilities to enable mobility impaired stakeholders to use the library optimally. While concluding that the barriers created because of communication, behavioral, transportation, and physical aspects are precluding disabled stakeholders from benefitting themselves from higher and professional education, which hinders them from self-employment or income generation.

On the contrary, a study conducted by Sanaman et al. [23] on university libraries in National Capital Region, India, concluded that libraries were adequately resourceful as they were getting updated with the latest technology for providing better services for disabled stakeholders. However, this study reported a lack of assistive aids for hearing impaired and locomotor disabled stakeholders.

Table 6 List of patents related to wheelchair

Patent name	Patents
Self-driving wheelchair for going upstairs and downstairs	CN108186217B
Electric wheelchair	CN103027803B
Wheelchair	WO2013093649A1
Auxiliary exoskeleton wheelchair	CN211409772U
Wheelchair with a seat base and a single front stem forming a cantilever-type frame	GB2483846A
Wheelchair	US10722409B2
A kind of reconfigurable wheel leg combination type wheelchair	CN103230320B
Tilting manual wheelchair	US10624803B2
Human-powered wheelchair with jackdrive™ propulsion system	US9398988B1
Sit-to-stand wheelchair	US20210145675A1
Mobility assistance device	US9913773B2
Standing wheelchair	RU2647777C2
Elevated height wheelchair	US10561548B1
Wheelchair with user-controlled tilt mechanism	US9408763B2
With security function and for the outdoor easy-to-use Portable manual stand-up wheelchair used	CN110022830A
Lightweight wheelchair	CN205459428U
Compact wheelchair assembly with removable wheels and methods therefor	US9901498B2
A kind of Multifunction restoring wheelchair	CN104382702B
Mobile chair apparatus comprising foot pedals	EP3207908B1
A kind of aiding upright wheelchair that front and back wheelbase is variable	CN110013395A

Dodamani et al. [19], in their study done on 185 Indian university libraries, focused on visually impaired stakeholders. They reported a lack of Braille and audiobooks with low availability of assistive aides i.e., SARA, DAISY, OCR scanner, Braille embosser, digital voice recorder, large print keyboards, screen magnifier. They further reported a low percentage availability of e-resources in an accessible format. Only one library had a tactile path, and the study reported that 78.3% of libraries lacked any written disability policy. The authors concluded that only 22.7% of universities have provisions to support disabled stakeholders with assistive devices and suggested that other universities should also follow a similar path for enabling libraries for all. They further opined that universities should take advantage of University Grants Commission's (UGC) financial support and guidance to make their institute libraries inclusive for blind stakeholders; this will be encouraging towards visually impaired stakeholders to use the facility.

Dhara [22] supported the need for optimum availability of assistive devices by sharing the data from NCPEDP, which shows an enrolment rate of 0.56% in higher

Table 7 List of patents related to cane/walking stick

Patent name	Patents
Walking stick for conveniently walking on uphill and downhill paths	CN104799511A
Walking aid	CN111107763A
A multi-configuration walking apparatus	WO2012078164A1
Crutch or walking stick with a spring-mounted and push-button-up mechanism which can be folded in and out in the lower part—crutches/walking stick stand as a tripod or four-legged; Crutch or cane as without further support /leaning self-standing, independently parkable and then reusable Gehhilfsmittel	DE202013001027U1
Walking aid	KR20120022474A
Multifunctional walking cane and associated use thereof	US10149522B1
A walking aiding device for a hemiplegic patient and a control method thereof	KR101913187B1
One kind of auxiliary stair activity crutch	CN107126349A
Elbow clutch	JP2017029335A
Multifunctional axillary crutch	CN105310866A
Adjustable anti-skidding physiotherapy stick	CN213284172U
A kind of multi-function walking stick	CN206822156U
Cane tip and cane	JP2013048880A
Portable walking aid device with wheels	US10327976B1
Robotic cane device	JP2016105770A
Motion aid assembly with electric-powered wheelchair function	TWM522722U
Motorized walking and balancing apparatus	US9839570B2
Walking cane and reacher device	US10034522B1
Multifunctional walking stick used for the disabled	CN202842575U
Gait devise with a crutch	CN105246450B

education while 3% seats are reserved for persons with disabilities in higher education institutes. Similarly, in their study, Dodamani et al. [19] report the need for technologically updated assistive devices in libraries, and McNicholl et al. [9] supported the need for updated assistive devices technology for students with disabilities in higher education.

The gaps between guidelines and databases on how to accomplish inclusivity in an educational institute make it unapproachable. This compels and poses utmost urgency for conducting primary research on the current situation of higher educational institutes in India.

5 Conclusion

Present review provides comprehensive information on the assistive devices that could be used in HEIs to help stakeholders with disabilities. The data presented on assistive devices and systems has been compiled based on the type of activity required in HEIs. The database will be a valuable resource for researchers working in inclusivity, universal design, education, higher education institute, or assistive devices. Current studies in this domain lack substantial information; this calls for primary research on the state of the art of inclusivity in Indian higher educational institutes. Data collection can be done by conducting interviews with different institute stakeholders and connecting with the disability offices to collect data on current policies being followed [27]. The intended research would create a state of art database of policies, assistive devices, assistive services, and infrastructure provided in institutes.

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Musculoskeletal Pain Experienced by the Marble Cutting Workers in Marble Industries at Kishangarh District, Rajasthan

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Abstract Musculoskeletal pain refers to pain in the muscles, bones, ligaments, tendons, and nerves may be in one area of the body or throughout the body. Musculoskeletal disorders (MSDs) and pain are the major causes for workers' inability, expense raise, and efficiency reduction in industries. A large number of persons are engaged marble based industries. Despite of the technological development for lifting bulky marbles and cutting them, the role of a human being cannot be denied. The present study was undertaken, to gain an insight regarding the musculoskeletal pain experienced by the Marble Cutting workers involved in cutting Marble slabs into small tiles at the Marble Industry with an experience of minimum 2 years. A questionnaire was developed to collect data on the pain experienced by the respondents since the past 12 months and last 7 days in their body parts while doing the various movements with each body part, resting and by carrying out the activity as reported by them. The mean age of the respondents was 36.77 years. The mean years of working experience in the present marble industry was 5.66 years. On calculating the weighted mean for perceived musculoskeletal pain for each body part of the respondents for past 12 months, it was revealed that back was ranked highest followed by palms and shoulder. The findings of the study will aid Marble Association of Kishangarh and the Workers to gain an understanding regarding the issues faced by the workers and thus aiding in regulations for the same.

Keywords Musculoskeletal pain · Marble · Marble cutting workers · Marble industry

1 Introduction

Marble industry in Kishangarh comprising of more than 500 industries employing more than thousand persons employed of direct and indirect labourers. The marble industry is emerging as an important industry for the construction agencies [1]. The

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marble cutting in tiles is done on marble cutting workstation. The marble cutting machine on which the small slabs are cut making tiles or decorative pieces requires the worker to adjust the marble on the machine and hold it till the blade cuts the marble through. In order to improve the performance and maintain the health of the marble cutting worker, the environment of the workplace need to be adequate. Health of the worker is important because it affects the efficiency and the production of the industry worker but at the same time affects the total production of the industry. The loss of human resource is the loss to the economy of the nation. Stone quarrying, cutting and masonry is one of the many industries which involve moderate to heavy manual work. Due to the nature of manual work and use of tools, stonecutting job may potentially cause work-related upper limb musculoskeletal disorders. The review of literature highlighted that work-related musculoskeletal disorders/occupational disorders have been investigated and reported for workers from various sectors in India. These include computer operators/keyboard users, goldsmiths, stone carvers and workers from sand core making, mining and weaving industry [2–8]. There are very few studies been conducted on marble cutting workers within and outside India [9–11]. A dearth of researches was found focusing on Musculoskeletal Pain experienced by the Marble Cutting Workers. Thus, the present study was conceptualized. The findings of the study will be helpful in making the owners of the marble industries aware about the existing working environment of their industry. The findings will also be helpful for the marble cutting workers in the industry as it will help them review their postures and adopt the improved ones to reduce musculoskeletal pain. This has a direct relationship on the increased productivity and output of the marble industry.

Objectives

1. To identify the musculoskeletal pain as perceived by the respondents working in the marble industry.

2 Methodology

The present descriptive study which was carried on a sample comprising of 220 workers involved in cutting Marble on the Marble Tile Cutting Workstation working in the Marble Industries of Kishangarh Tehsil of Ajmer, Rajasthan. Purposive sampling design was utilized for selecting the sample. The study was limited to the respondents having a minimum work experience of 2 years in cutting marble and who came regularly to work. The present research was also limited to the marble cutting workers who were not suffering from any chronic or acute disease. An informed consent before conducting the interview via interview schedule was taken from the Industry Owners and the respondents.

Section 1 of the Interview Schedule comprised of information regarding the demographic profile of the marble cutting workers. Section 2 included the information on Perceived Musculoskeletal Pain experienced by the respondents was collected

to identify the musculoskeletal pain experienced while doing certain movements namely lifting weight (overhead, at chest level, below chest), while carrying the weight and keeping the weight on a surface, while tightening a screw, while sitting on floor/mattress, while squatting, while running, while standing still, pain experienced while at rest, and identifying whether pain interferes in daily activities since the past 7 days and 12 months. The procedure used to analyze the data were categorization, coding, tabulation and statistical analysis. Analysis of Variance, was carried out to test the hypotheses postulated for the study using STATA, 14.2.

3 Findings

3.1 Background Information

The mean age of the respondents was 36.77 years. Less than one half of the respondents (47.73%) belonged to the age group of 35–40 years. More than one-third of the respondents (34.09%) had educational qualification upto Primary Education (upto 5th standard). The mean years of experience of the respondents was 12.26 years. Slightly less than on half of the respondents (41.36%) had experience of working for 11–15 years in the marble industry. The mean years of working experience in the present marble industry was 5.66 years. Slightly more than two-third of the respondents (66.82%) had a less than or equal to 5 years of working experience in the present industry. Majority of the respondents (97.27%) were right-handed.

3.2 Perceived Musculoskeletal Pain

The subjective data regarding the perceived pain of the respondents in the body parts namely neck, shoulders, arms, elbows, wrists, palms, back, hips, thighs, legs, knees, feet and ankles while doing various movements while performing their task of cutting tiles from waste marble slabs, and during rest. The data regarding the confirmation of existence of musculoskeletal pain among the respondents through their medical report information about visit to a doctor for curing the pain could not be gathered as the economic background of the respondents was very poor. An enquiry was also made if the respondents visit any nearby Public Health Center or any local doctor but the respondents quoted that their work gets suffered if they visit doctors so they avoid going for checkup. Very few respondents had visited the doctor for their pain related queries but they visited a physician and also did not complete the full course prescribed to them stating that their work was suffering.

3.2.1 Perceived Musculoskeletal Pain as Perceived by the Respondents in Their Neck

While analyzing the data for the pain experienced in movements of neck while pursuing their task of cutting marbles in the past 7 days depicted that slightly more than one-tenth of the respondents (14.55%) experienced pain while rotating their neck clockwise and anticlockwise as compared to the other neck movements. A similar number of respondents reported that pain hindered the continuance of their daily activities. One-tenth of respondents (10.91%) were found to be experiencing certain pain while resting. It was highlighted in the findings, very few respondents (6.36%) experienced pain while moving the neck to the left side since there were very few controls on the left side of the workstation. The findings also revealed that all the respondents who were experiencing pain in either movement of the neck since 7 days reported that the pain hindered in continuing their daily work. On analyzing data of perceived Musculoskeletal Pain in the past 12 months it was revealed that more than one-half of the respondents (54.54%) were found to be experiencing musculoskeletal pain while moving their neck upwards in the past 12 months. On scrutiny of the data it was highlighted that 42.73% of the respondents were found to be experiencing pain while resting since the past 12 months. The findings were in line with the studies conducted on nine hundred forty-one unionized hotel room cleaners and female production assembly workers in Estonia respectively wherein similar findings have been reported [12, 13].

3.2.2 Musculoskeletal Pain as Perceived by the Respondents in Their Shoulders

The data on the pain experienced by the respondents in the past 7 days revealed that slightly more than one-tenth of the respondents (14.55%) were experiencing pain in the left shoulder while lifting the marble slab which could be due to inflammation of the shoulder muscles. Very few respondents (4.09%) were suffering from pain while lifting marble slab overhead. It was observed that the heavy marble slabs were rarely lifted above chest level by the respondents thus not causing pain while lifting marble slab above chest level. Slightly less than two third of the respondents (63.64%) experienced pain in the right shoulder while carrying the marble slab and while rotating the shoulder clockwise in the past 12 months. Pain in left shoulder while carrying marble was experienced by 60.91% of the respondents in the past 12 months. Slightly more than one-half of the respondents (56.36%) experienced pain in the right shoulder while keeping the marble slab. Slightly more than one-half of the respondents (55.45%) were also experiencing pain in right shoulder while resting and in left shoulder while rotating shoulder clockwise in the past 12 months.

3.2.3 Musculoskeletal Pain as Perceived by the Respondents in Their Elbows

While interrogating the respondents on experiencing pain in their elbows, nearly one-tenth (10.91%) were found to be experiencing pain in the right elbow while at rest in the past 7 days. The assessment of the perceived musculoskeletal pain in elbows since 12 months elicited that 59.09% of the respondents were experiencing pain while doing supination movement (i.e. while doing a movement of tightening a screw). Slightly more than one-half of the respondents (50.90%) experienced pain in the right elbow while carrying the marble slab which can be speculated to be due to golfer's elbow (inflammation of tendons) since 12 months. Pain in left elbow while tightening the screw in the past 12 months was experienced by 47.27% of the respondents.

3.2.4 Musculoskeletal Pain as Perceived by the Respondents in Their Wrists

The data on the musculoskeletal pain since the past 7 days as perceived by the respondents in their wrists highlighted that one-tenth of the respondents (10.00%) experienced while resting in their right wrist. Pain in their right wrist while at rest was experienced by 8.18% respondents. The data also revealed that more than one-half of the respondents (53.64%) experienced pain in the right wrist while rotating it clockwise since the past 12 months. One-half of the respondents (50.00%) experienced pain in the right wrist while carrying the marble slab. It was reported that majority of the respondents were right-handed thus experiencing more pain in the right wrist. Pain was experienced in the right wrist while keeping the marble slab on a surface of the workstation by 44.45% of the respondents since the past 12 months. The findings concluded that there were a higher number of respondents experiencing pain in the past 12 months than the past 7 days. The respondents were also found to be ignoring medical attention since they did not belong to good economic background.

3.2.5 Musculoskeletal Pain as Perceived by the Respondents in Their Arms

The data revealed that slightly less than one-tenth of the respondents (9.09%) experienced pain since 7 days in their left and right forearms while carrying the marble slab. A similar number of respondents (8.18%) experienced pain since 7 days while keeping marble slab on the surface in right and left forearm. The data revealed that pain experienced by the respondents in their arms revealed that nearly two-third (62.27%) of the respondents experienced pain since 12 months in their right forearm while carrying the marble slab. Slightly more than one-half of the respondents (54.09%) were found to be experiencing pain since 12 months in their left

forearm while carrying the marble slab. Slightly less than one-half of the respondents (49.09%) had pain in their right forearm while keeping the marble slab on the surface of the workstation. The respondents (40.91%) also experienced pain in the left forearm while keeping the marble slab on the surface of the workstation since the past 12 months. The findings concludes that the respondents had developed more chronic pain since there were more number of respondents experiencing pain since 12 months, it could be due to higher number of respondents had experience more than 2 years.

3.2.6 Musculoskeletal Pain as Perceived by the Respondents in Their Palms

The results revealed that slightly less than one-tenth of the respondents (7.27%) experienced pain since 7 days in their right and left fingers while grasping the marble slab. The data highlighted that more than two-third of the respondents (68.18%) experienced pain since 12 months in their right-hand fingers while gripping and grasping the marble slab and tile. The data also revealed that 61.82% of the respondents were found to be experiencing pain in their left-hand fingers while gripping and grasping an object since the past 12 months.

3.2.7 Musculoskeletal Pain as Perceived by the Respondents in Their Back

The assessment of the musculoskeletal pain as perceived by the respondents in their back revealed that one-tenth of the respondents (10%) experienced pain since the past 7 days in their upper back and lower back while carrying marble slab, while bending down and while keeping the marble slab on the surface of the workstation respectively. A relatively higher number of respondents (86.36%) were found to be experiencing pain since the past 12 months in their lower back while keeping the marble on the surface of the workstation and while carrying the marble slab. Slightly more than three-fourth of the respondents (76.36%) experienced pain in the upper back while carrying the marble slab and in the lower back while lifting the marble slab below chest level since the past 12 months.

3.2.8 Musculoskeletal Pain as Perceived by the Respondents in Their Hip

Less than one-tenth of the respondents (7.27%) experienced pain since the past 7 days in their right and left side of the hip while sitting on a chair. Very few respondents (4.55%) were found to be experiencing pain in left and right side of the hip while standing to sitting and sitting to standing. The data also revealed that 20.91 and 20% of the respondents experienced pain in their right side of the hip while sitting on a

chair and while in squatting position since the past 12 months. It was also revealed that 18.18% of the respondents were found to be experiencing pain in their left hip while in squatting position followed by 17.27% who experienced pain in the left side while sitting on the chair since the past 12 months.

3.2.9 Musculoskeletal Pain as Perceived by the Respondents in Their Knees

One-tenth of the respondents (10.00%) experienced pain since the past 7 days in their left knee while resting. The respondents complained to the researcher that they had maximum pain in their knees and that it was very difficult for them to continue a routine life due to the pain. While investigating the perceived pain experienced by the respondents in their knees, it was reported that slightly less than three-fourth of the respondents (72.73%) were experiencing pain since the past 12 months in the right knee while carrying the marble slab. On scrutiny of the data of pain experienced in the past 12 months it was seen that that respondents experienced pain in the left knee while carrying marble slab was reported by 68.18% of the respondents. The data also revealed that 60.91% of the respondents experienced pain in right knee while sitting in squatting position and while sitting to standing. Slightly more than one-half of the respondents (56.82%) were found to be experiencing pain in the right knee while keeping the marble slab as well as while sitting to standing in the left knee. Slightly more than one-half of the respondents (55.45%) experienced pain in the left knee while sitting in squatting position in the past 12 months.

3.2.10 Musculoskeletal Pain as Perceived by the Respondents in Their Thighs

While investigating the pain experienced by the respondents in thighs revealed that slightly less than one-tenth of the respondents (8.18%) were found to be experiencing pain since the past 7 days while carrying the marble slab on both thighs. Carrying the marble slab also induced pain since the past 12 months in right thigh among 44.09% of the respondents since the past 12 months. Sitting to standing was also one of the reasons for inducing pain among 40% respondents in right thigh and among 34.45% respondents in their left thigh since the past 12 months.

3.2.11 Musculoskeletal Pain as Perceived by the Respondents in Their Legs

Very few respondents (4.55%) experienced pain since the past 7 days in the right leg while carrying the marble slab. Slightly more than one-half of the respondents (50.91%) were found to be experiencing pain since the past 12 months while carrying the marble slab in their right leg. Slightly less than one-half of the respondents

(46.36%) experienced pain in the right leg while running Pain was experienced in the left leg due to carrying marble slab by 44.09% respondents. The data also revealed that 42.73% of the respondents were found to be experiencing pain while sitting to standing since the past 12 months followed by 42.27% of the respondents experienced pain while keeping the marble slab on the surface of the workstation.

3.2.12 Musculoskeletal Pain as Perceived by the Respondents in Their Feet

It was observed that very few respondents (4.55%) were found to be experiencing pain since the past 7 days while carrying the marble slab in both feet. The data also revealed that 29.55% were found to be experiencing pain since the past 12 months in the right feet while carrying the marble slab indicating that carrying weight induced pressure on the feet of the respondents. Slightly more than one-fourth of the respondents (27.73%) also experienced pain in their left feet while carrying the marble slab. Running was also found to be one of the causes for pain among 21.36% of the respondents in their right feet and among 18.64% respondents in the left feet since the past 12 months.

3.2.13 Musculoskeletal Pain as Perceived by the Respondents in Their Ankles

The data revealed that 8.18% of the respondents experienced pain in the past 7 days in their right ankle while sitting in a squatting position and in left ankle while carrying the marble slab. Further investigation on the musculoskeletal pain experienced by the respondents since past 12 months revealed that slightly more than one-half of the respondents (54.55%) experienced pain in right ankle while sitting in squatting position. The data in the table also highlighted that 52.27% of the respondents were experiencing pain in the right ankle while carrying the marble slab. 43.18% of the respondents were found to be experiencing pain in the left side while sitting in squatting position.

3.2.14 Overall Perceived Musculoskeletal Pain in Body Part

On calculating the weighted mean for perceived musculoskeletal pain for each body part of the respondents for the past 7 days and past 12 months, it was observed shoulder was ranked highest in the past seven days followed by elbows and back. The third in number was palms in the past seven days as the palms were in direct contact with the vibration produced by the workstation. The analysis of the perceived musculoskeletal pain in the past 12 months it was revealed that back was ranked highest followed by palms and shoulder.

Hypothesis Testing

To find out the difference between Perceived Musculoskeletal Pain experienced by the respondents with their Age, Years of Working Experience, Perceived Health Status "Analysis of variance" was computed. The results showed in Table 1 a significant variation (F value 0.3, α 0.01) was found in the Perceived Musculoskeletal Pain of the marble cutting workers in various parts of the body with their Perceived Health Status during work. Hence, the null hypothesis was partially rejected. This reflected that the Perceived Health Status of the respondents during their work varied (*p*-0.003) with their Perceived Musculoskeletal Pain experienced by the respondents. The F value was not found to be significant hence, it did not show any variation in the Perceived Musculoskeletal Pain of the marble cutting workers in various parts of the body with their age, years of experience and Perceived Health Status (after work). Thus, the null hypothesis was partially accepted. Hence, it was inferred that the Perceived Musculoskeletal Pain of the marble cutting workers in various parts of the body had no significant effect with their age, years of experience and Perceived Health Status (after work).

$Ho_{1.1}$: There is no variation in the Perceived Musculoskeletal Pain experienced by the respondents with their Age, Years of Working Experience and Perceived Health Status.

Table 1 Analysis of variance showing variation in the perceived musculoskeletal pain experienced by the respondents with their age, years of working experience and perceived health status

Selected variables	df	Sum of squares	Mean squares	F value	Level of significance
Age					
Between groups	2	6251.7	3125.9	2.9	N.S.
Within groups	217	230,808.8	1063.6		
Years of experience					
Between groups	2	605.7	302.9	0.3	N.S.
Within groups	217	236,454.8	1089.7		
Perceived health status (during work)					
Between groups	3	14,473.7	4824.6	4.7	0.01
Within groups	216	222,586.9	1030.5		
Perceived health status (after work)					
Between groups	4	5544.4	1386.1	1.3	N.S.
Within groups	215	231,516.1	1076.8		

Note * N.S. = Not significant, df = Degrees of freedom
p value 0.003

4 Conclusion

The study concludes that the respondents experienced more pain in shoulders followed by elbows and back in the past 7 days. The respondents also experienced pain in their palms in the past seven days as the palms were in direct contact with the vibration produced by the workstation. The analysis of the perceived musculoskeletal pain in the past 12 months it was revealed that the respondents experienced pain in their back followed by palms and shoulder. The researcher can conclude that there can be some regulatory measures be taken for the Musculoskeletal Pain being suffered by the Marble cutting workers. The researcher had also developed an intervention programme for reach but due to COVID 19 lockdown and restrictions only two industries were working thus the researcher tried to orient and sensitize the industry owners and the workers that correct posture while lifting marble slabs and giving rest is important. The researcher opines that the labour protection laws must be implemented well and be timely scrutinized for its implementation.

5 Implications

The study reflected clear implications for the need to educate the stakeholders regarding Ergonomic Practices in Marble Industry. An ergonomic intervention programme can be used to create awareness and promote training to the employees and using protective aids while working in the industry. The Kishangarh Marble Industry, labour laws need to meet the challenges faced by the daily wage workers in unorganized sector.

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User and Market Research with Proposed Concepts for Ceiling-Fan Dust Cleaning

Marilyn Supriya Albert, Sudarshan Katti, and Arunachalam Muthiah

Abstract Ceiling-fan cleaning tools/equipment are necessary household items in India. Considering the present market, very few cleaning tools (products) are available for the ceiling fan's dust removal process. These products weren't successful among the users due to several ergonomic and usability issues. However, there isn't any research article regarding this information/ fact. Therefore, this paper aims to obtain information regarding the user's experience with existing ceiling-fan cleaning tools/equipment and propose few new designs for addressing the user's problems. Initially, market research has been conducted to understand the needs/expectations of the users regarding cleaning methods and existing equipment. A user survey was performed using a questionnaire, which helped in further insight into the design process. This survey includes several questions regarding the aforesaid issues during the ceiling-fan cleaning task. Using the brainstorming technique, various concepts have been generated. The cleaning tool's new conceptual designs were developed to address the user needs (functional and aesthetical) and expectations. From the result, it's been observed that the user felt some pain/ discomfort in certain body regions like the neck, shoulder, and arm, as well as a major strain on the lumbar area. The other major concerns were also observed such as reachability, ease of usage, and ease of implementation (interactions with the product) while using the existing ceiling-fan cleaning tools/equipment. Considering these user's concerns, few concept designs were proposed, which are expected to be a better design for the ceiling-fan dust removal process.

Keywords Design · SCAMPER · Market research · Online survey · Job screen

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1 Introduction

Cleaning is of significance in a human being's life, there are different types of cleaning such as professional, industrial, household, etc. Categories as such show its importance. Cleaning as a responsibility has developed into a routine. For example, dusting beds, cleaning the study desk, all these tasks become a part of one's daily life. These tasks involve cleaning, not only determine personality but make the environment more hygienic, suitable for human occupation, clarity, and sustainability.

Quality indoor air is important, without cleaning the air remains filled with dust particles, sediments in the air that settles on devices or items around the house thereby contributing to unclean feeling. These are the reasons which give way to allergies, respiratory issues, and other sicknesses [1–4].

This research paper focuses on household cleaning and a particular aspect in every household. Household cleaning in India varies drastically from the cleaning done in other parts of the world. The methods or techniques are adopted, invented, and innovated by the users. While working on this research paper, many observations were proof of the kind of techniques and tools used. The geographical areas matter much when considering cleaning. Navigation through the brief, researching, as aforesaid, humans are the primary stakeholders of cleaning, users constituted men and women, 70% of women in India are marked for this job of cleaning, considering all over India, sweepers, house helps, etc. all constitute women and when cleaning is mentioned the first thing that comes to mind is women with a broom/swob stick. Cleaning causes a lot of physical strain and stress, accounting for badly designed tools and equipment. Therefore, this research emphasizes on ergonomically designing tools that reduce the physical strain while performing cleaning tasks [5–7]. There are only countable tasks that one remembers when considering household cleaning, and one such task is cleaning the ceiling fan. The research paper focuses on the task of cleaning ceiling fans using a tool or equipment. The ceiling fan plays a significant role in every household but is often taken for granted. The methods adopted for cleaning the ceiling fans vary from one household to the other forming a pat-tern. Observations in different environments, helped in detecting specific problems considering the task, according to which solutions were conceptualized.

2 Methods

This is an unexplored topic in the industry, therefore there were a lot of structured interviews with open-ended and closed-ended questions, this included quantitative and qualitative research. These research methods helped in gaining insights on the issue. As similar research papers [8–10], a general product development process had been fellow to fulfil the objects.

2.1 Online Survey

The exploratory study started with an online survey, it included both qualitative and quantitative portions of interviewing, preparation of questionnaires, and human testing of the tools used. This method was effective to understand the customer needs and expectations, and the variability in opinion, and the discovery of a pattern of behaviours followed by humans across the varied audience.

An online survey was conducted to explore the impact of dust and dirt on respiratory health, allergies, and other diseases arising at home. Survey participants were not limited to a single area/region/locality. Homes in metropolitan areas are spacious but because of the traffic and pollution, the need to keep the homes clean arises. When considering circulation of air, ceiling fan which plays a significant role in homes, therefore, making the center of attraction to cleaning. Therefore, the research continued with a survey to explore more possibilities and opportunity areas.

The survey mainly constituted of questions regarding the pain points, the different methods, tools, duration, and other open-ended questions to understand the scenario and the mindset behind the users and constituted the main question about the effect on functionality. The survey that was undertaken gave important points on comfort and implementation issues. The aesthetical factor played a part in tertiary concerns as the tools used were minimal.

The perceived issues are the ease of cleaning and the ease of access. The survey offered feedback and aided in the discovery of intervention areas. The task analysis for the floor cleaning process was done by Haslam and Williams (1999) [11]. Cleaning ceiling fans was the subject of a task analysis. From this survey, certain main needs were sorted out: The primary need being the smooth cleaning of the fan, the Secondary need being the easy reachability, and the Tertiary need, easy availability, and suitable aesthetic look and feel (Fig. 1; Table 1).

Fig. 1 Performing the task

Table 1 Estimations during the task analysis

• For reachability purposes, there is always a need for a ladder, stool, chair, or table (as a supporting factor). Transportation from one room to another
• Accessing different clothes or mediums, therefore to and fro climbing, increases fatigue
• Adjustment of height and the fan blades at the time of cleaning
• Gripping problems, causing pain and discomfort at the wrist, the arm, and shoulder. The strain on the knee and ankles (standing and balancing)
• Stretching and repeated movements across the ceiling fan causing discomfort and pain in the lumbar region and the arm
• Restriction in movement, decreasing accessibility to the other corners of the ceiling fan, lacking in holistic cleaning
• Dust fell onto the floor, which required double the work and effort by the user
• The time taken to clean each ceiling fan was appx. 10–15 min, which left the user exhausted to put the energy into cleaning the other fans

2.2 Be the Customer

Loopik et al. [7] Designers used a new way of looking at ceiling fan cleaning, by mirroring the pain and discomfort faced by the user being experienced by the design team. This was a test for the designers to see if they could replicate what the users' experience would be like in their home. Being a user, the spectrum of research widened and gave more opportunities of investigation further in detail which rede-fined the initial brief.

Ergonomic tool: Job Screen was used as the ergonomic tool to assess the risk factors that proceeded with performing the task.

While performing the Job Screen evaluation the tasks that were identified were: Exertion in the neck region while cleaning the fan (force load). Lifting the head, the body leaning forward in balance (deviation in an oblique position). Getting down off a ladder or stool multiple times to access equipment/ items for cleaning (Impact stress, contact stress). These were the tasks that were identified and the score evaluation was done later analyzing these tasks.

2.3 Market Research

There are a variety of products that are available on the market. The products, that are purchased by the users work on multipurpose functionality. External agents tend to damage or reduce the efficiency of the ceiling fans. These tools are based completely on functionality rather than aesthetic finish (Fig. 2).

As the research was done the existing products were segregated into two parts:

1. Globally available cleaners

Pros: They are most effective on designer fans.

Fig. 2 Existing products in the market

Cons: (a) They are not effective on fans that have stubborn dirt/dust, (b) They are limited to regular/ spring cleaning, (c) Referring to the affordability, these products were priced high, and not a part of the Indian household list. It was rarely found in homes.

2. Locally available cleaners

Pros: (a) They are effective on stubborn dirt/dust on the fan, (b) They are affordable and are included in the Indian household list, as most of the decisions about cleaning items are majorly made by women, (c) They are preferred as they are easily handled and maintained, irrespective of the gender of the person performing the task.

Cons: (a) They are not aesthetically designed therefore it gets less of market presence thereby increasing the market presence for the other high-end products, (b) Although it is easily available and accessible, it accounts for ergonomic issues in the user.

2.4 Concept Generation Using SCAMPER

Ideas were generated by using the simple method of brainstorming. The preliminary stage of ideation consisted of solutions that were based mostly on functionality, efficiency and ease of use. Out of these preliminary ideas, 5–8 ideas were shortlisted as concepts in certain design directions. By further iterations on these ideas, it was taken to the conceptual modeling phase. To assess the outer form, the assembly, and the parts the tools would constitute, Height altering, Holistic cleaning, Ease of usage, less pressure applied by the user, offering effective cleaning and tedious free.

SCAMPER was used in a further iteration of the concepts, discovering the endless possibilities for designing a tool [12]. All these concepts were designed to keep all these directions at the forefront. The concepts were evaluated and taken forth based on these factors.

3 Result

3.1 Online Survey

An online survey had from 100 participants and this helped in obtaining opinions and discovery of several problem areas, that this study needed to address. The age group of the participants was from 18 to 65 years (appx.). Out of these participants, 65–75% were women irrespective of housewives and the working class and 15–25% were men and the roles were reversed according to the household chores and availability of persons. Questionnaires, interviews, and observations, show a higher ratio of females than males, therefore hinting, that household cleaning is a basic necessity to the former, and the latter rarely performs them as an option. Almost, 50% of the females expressed their difficulties, pain, and discomfort in terms of physical efficiency and other factors contributing to making this task a tedious one.

- Physical efficiency: the physical efficiency decreased while performing the task, there were a lot of problems, pain, and discomfort which was reported by the users.
- Height and Reachability: the ceiling fan is placed at an approximate height of 7feet from the ground/floor and often a need arises to use a support to reach the fan to clean.

As per the current height range, the average height of an Indian male is 5.8 feet (177 cm) and the average height of an Indian female is 5.3 feet (162 cm). This shows that there is a strain caused in terms of reaching the ceiling fan in general and more in women, hence causing these physical inefficiencies and a height issue was raised in these surveys. There is no tool/equipment which addresses this issue, therefore making it an essential problem area to be worked upon.

- Other factors: In addition to these problems, other concerns were mentioned by the customers/users.
- The dirt accumulated on the ceiling fan pushed toward the floor increases the work of the user and therefore an experience of extreme fatigue, making it a difficult task.
- The increased dust accumulation on the ceiling fan circulating the air around the room influences the devices and also provides an unhygienic environment.
- This survey helped in identifying that apart from the users, there is increased damage caused to the device itself, thereby reducing the efficiency and the appearance too.

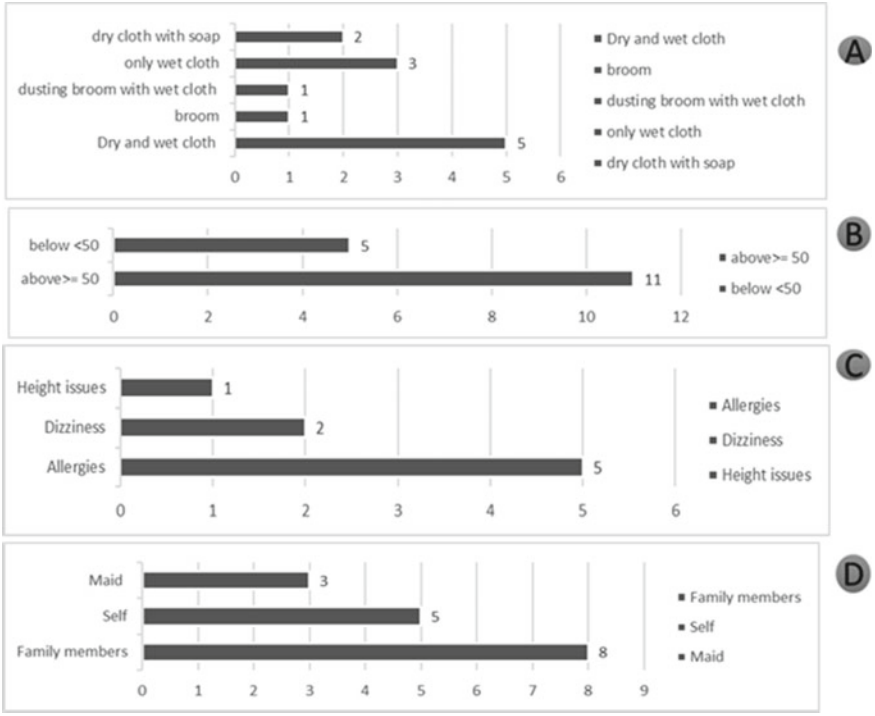

Fig. 3 **a** Mode of cleaning; **b** summary of the age group who clean the most; **c** bodily issues which arise during the task; **d** stakeholders a part of the task

- With the availability of tools/equipment for cleaning of ceiling fans, there is less percentage of people/users/customers who were aware of tools that exist in the market and the majority invented their own tool/techniques/methods of cleaning.
- The house helps handle the device and the tools roughly, therefore the users prefer to do the work themselves. The tools are either too difficult to interpret or too easy to handle, this makes them have no control, which increases the efficiency of cleaning but reduces the performance of the devices (Fig. 3).

This survey helped in identifying the problems in-depth and understanding the scenario and mindset with which the user performed this task. Below were a few graphical representations of the results (see Fig. 2).

3.2 Be the Customer

The task was performed under much awareness and being observant of the sensations, being the customer, and imitating, helped in identifying and also was proof to the concerns expressed by the primary stakeholder. While performing the task in the

Table 2 Suggested design modifications or design directions

• A tool devised in such a way it would be used in regular cleaning of the fan (to maintain regularity) as the other parts of the house are cleaned in the same way, part of the daily routine
• The tool devised should be tedious free for the user
• Considering the growing popularity of eco-friendly and organic substances, the tool should be user-friendly and also especially women-friendly too
• a tool that creates the need for other precautionary measures while cleaning
• Devised to alter according to the user and their needs (flexibility)
• Height altering tool/device, to avoid strain on the user
• To device a solution for cleaning the fans by maintaining the quality of the fans
• The process of cleaning should be carried out by a device/tool, to avoid the doubling of work
• The tool should be easy to interpret, and easily perceivable
• The tool is designed to be affordable, with affordable technology and low manufacturing cost

work environment, there were a lot of factors in terms of reachability, in-creasing safety issues as well as the need to reach the far end of the blades., therefore, reducing the efficiency of the task performed, thereby leaving the customer/user tired with an impression of disgust towards the cleaning of the ceiling fan.

Keeping all the senses active, this was noted,

- The eyes and the sight were affected due to the prolonged head lifted position causing pressure on the neck and the head, hence making the user dizzy and higher chances of the dust falling into the eyes of the user, causing inefficiency again.
- While performing the task, there was a need which arose of holding the fan to keep it steady (Fig. 1) this makes performing the task unhygienic without precautionary measures.
- Once the task is performed and the ceiling fans are cleaned, the intense handling of the fan during the task, which affected the fan and its efficiency and produced a peculiar noise, hinting at loosened parts.

These pointers or directions were considered while developing designs of holistic cleaning (Tables 2 and 3).

3.3 Market Research

Observance during the market research, all these products are ranged from the lowest price of 100–500 rupees to the highest range of 1000–4500 rupees, these are the range of the dusters for ceiling fans. Many local brands occupy 60% of the e-commerce and traditional markets by their products of cleaning. These accounts to nominally priced cleaners. The vacuum cleaners equipped with the cleaners for the ceiling fans were much higher priced as they produce supreme quality products. Brands such as

Table 3 Ergonomic assessment tool: job screen

1	Force-highest level of exertion-neck/upper back	4
2	Posture-deviation in the posture-extreme deviation	4
3	Repetitive task-climbing up and down and circular	
	Motions on the fan-Legs and R upper arm/shoulder-repetition	2
	L upper arm/shoulder-sustained 6–10 s	4
4	Contact stress—The knees are rested, pressed against the ladder steps. Upper body leans towards the ladder	< 2 h per day
5	The exposure level—nominal	< 30 min per day

Dyson, Dirt Devil 320 reach upright vacuum, Eureka Forbes, and many more offer vacuum cleaner equipped with attachments that serve multifunctional purposes.

The main insight included affordance as primary and while evaluating a product, the price ranges were compared. The mindset is such that the lowest range of tools are purchased, or the normal duster cloths are used with the help of an external agent. This makes it unsuitable for ceiling fans.

3.4 Concept Generation Using SCAMPER

Considering the pointers and the directions which are provided in Table 2, ideas were generated of different kinds. These ranged from solving the primary need of cleaning the ceiling fan to the concern of maintaining safety and smooth interaction between the user and the device.

These were the concepts that were designed through shortlisting the ideas and applying the method of SCAMPER (Substitute, Combine, Adapt, Modify, or magnify, put to another use, Eliminate and Reverse.) and other methods such as lateral thinking, which helped in further iterations. Thus, providing 4 concepts to consider as potential solutions to be worked on further (Fig. 4).

Concept 1: This idea was conceptualized to avoid the secondary cleaning that arise as a problem. The device consisted of a motor which helps in collecting dust/dirt. The inception of this concept was it to be a handheld device, mainly focusing on efficiency of cleaning. As further iterations/modifications were done, the concept evolved and imitated a conveyer belt, thus replacing/recycling the cloth immediately. Thereby preventing the accumulation of dust on the cloth after each clean, and keeping the whole process hygiene [13]. A provision was designed to support an external handle to repair the height issue, usage according to the user's requirement.

Pros: (a) Keeps the process hygienic, (b) The provision for the handle gives the user the flexibility to use a handle of their choice and no restrictions in height, (c) The dust is collected and avoids the extra work, and since it is motorized saves the time of the users too.

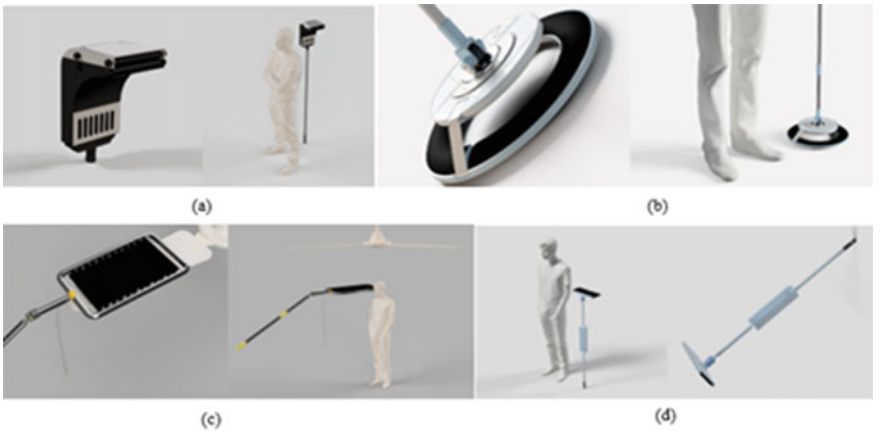

Fig. 4 Potential concept models. **a** concept 1, **b** concept 2, **c** concept 3, **d** concept 4

Cons: (a) There are chances of the motor getting affected although the compartments are made, (b) There may arise a problem with cleaning/maintaining the tool/equipment, (c) A handle wouldn't be available in every user's house to use it in the provision given.

Concept 2: This idea was conceptualized to be a multipurpose tool. It focused on the problem of storage and inefficient cleaning. This multipurpose tool, started as an inspiration of the current swob-sticks in the market, therefore, replicating a look alike with more brushes to increase the efficiency of cleaning. So, this device conceptualized for both the surfaces. The adjustments on the handle exist but this also works for two purposes, and the main focus here is the adjustment of height for the convenience of the users.

Pros: (a) The usage of the tool/equipment is multipurpose which is similar to the existing tools in the market. (b) The two surfaces for cleaning, helps in performing two tasks, therefore, saving time and storage space.

Cons: The gap between the surfaces might in the tool might cause damage to the fan.

Concept 3: This idea was conceptualized based on solving the problem cleaning the ceiling fan. This tool was ideated through biomimicry. Mimicking the movement of the caterpillar, the fan fold structure helps in collecting the dust and wiping the surface off clean. There are several adjustments provided on the handle, keeping in mind the storage issue and the height issue. The concepts main benefit was to maintain efficiency in cleaning the blades of the fan, to avoid much strain. All the actions of the tool are controlled by a string. The tool follows sustainability by a recyclable and a washable cloth being provided.

Pros: (a) The joints in the tool make it compact in terms of storage, (b) The mechanism is a simple pull and push, which is familiar to the users, (c) Aluminum and stainless-steel exhibit sustainability instead of plastic.

Cons: (a) The positioning of the tool on the ceiling fan might impose strain on the user, (b) During dust collection, there can be fine dust particles that will be left out, (c) The weight may be exerted on one area of the tool, therefore, creating imbalance in handling the tool.

Concept 4: This idea was conceptualized considering the problem of cleaning the blades. The tool was designed with a difference in the handle. The handle consists of a provision for storage for all the attachments. This also offers a support to hold the tool while cleaning. The method used in conceptualizing was lateral thinking and substitution of design elements from other cleaning tools to make the solution more efficient and beneficial to the user/customer. This tool operates on slide and push mechanism, the upper part of the cleaner is divided into three parts, as this would make it easier to clean the blades of the fans. For bringing about reusability, washable pads. The secondary attachment helps in cleaning the other parts of the fan. It is designed in such a way to reach the unapproachable corners of the ceiling fan.

Often the cost of the products increases due to use of sensors and immense technology but this sensor being a low cost one makes the product affordable and eliminates the concerns of the latter. The mechanism is controlled by a simple pump which is part of the handle, therefore, adjustment of the height is an added benefit [14]. The frame is fitted to a square frame which helps in adjustment of the circular frame, according to the requirement of the users.

Pros: (a) This structure is similar to the ones existing in the market; therefore, the price also doesn't vary much when in terms of affordability, (b) The provision built in the center of the tool, helps the user to develop a better grip, (c) When the tool is in working position, it does not grip the blades and there is a gap which is maintained to avoid damage to the fan, (d) It can also be used to fulfil two tasks on two surfaces.

Cons: There is a possibility that extra pressure can be exerted when not operated by the buyer (oneself) itself.

3.5 Concept Selection

Concept 2 is compatible the directions, concerns, and needs of the users as per Table 2. This solution solves the problem of reachability and effective cleaning. A multipurpose tool which supports cost cutting, helps in solving the concerns of affordability. Every product has advantages and disadvantages and needs immense iteration and validation to get a suitable solution. The in-detail pros and cons of each of these concepts will be provided in the final research paper (Table 4).

Table 4 Concept selection Using Pro's & Con's method

Pro's	Con's
1. There is the ease of implementation and ease of use in relationship with the user	1. The head tilted in the upward direction; this position persists
2. There is less pressure applied to the ceiling fan making it damage-free	2. Pressure on the shoulders, arm, and neck exists, because of the operation of the tool. Unless a power tool/device
3. The microfiber cloth as a material makes it easy to reuse (washable) and replaceable	3. Possibility in minor alterations of the fan blade angle due to cleaning may occur
4. The mechanism used is simple, push and pull. One which is familiar to the users	4. Possibility in disposition of the fan from the ceiling given the rough handling of tools
5. Conceptualized to be minimal with a plastic body and aluminium handle with less cost	
6. Gripping provided is useful to the customers as a covering for attachments and also a gripper,	
7. Increased flexibility in terms of use and structure	
8. The flexible structure helps in easy cleaning of the fan blades, as those are the parts there arise a difficulty	
9. Solves the problem of reachability and maintains complete contact and a hygienic cleaning	
10. Even if technology plays a part here, the costs are cut by using low budget technology to prevent the burden on users	

4 Conclusion

It is concluded that the user & market research of ceiling-fans dust cleaning products was established considering the problems of existing methods to clean the fan. The methods and techniques listed in this study helped in developing preliminary concepts addressing the needs of the customer. The selected simple dust cleaner has limitations which still needs to be developed considering the factors of functionality, experience and interaction (cognitive, aesthetic and product development).

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The Ergonomics of Play: Recalibrating 'Play Spaces' of Thiruvananthapuram Government Primary Schools Toward Multiplicity

Eva Thomas and Aishwarya Padmanabhan

Abstract The act of play is ambiguous, temporal, transcendental and transformative. To play, is to position oneself relative to the other, suggesting a notion of power or even challenging it. To play, is to be - to identify oneself or to even imagine oneself as multiple beings behind the mask of the body. To make space for play and to design for it is often met with basic design guidelines irrespective of the different ergonomic requirements of various users, gender, ability, location, socio-cultural context, or space availability. This leads to the act of play being regulated, controlled and often restrictive for children in the process. The paper, therefore, intends to investigate existing play space design as constructs of inherent hegemonic sociocultural systems of the school as an institution by mapping activity patterns of children in four lower primary government schools of Thiruvananthapuram that encapsulate following parameters: designated play area, (non) presence of play equipment and the physical components of play spaces. Opening an enquiry regarding 'what makes architecture playful', the paper offers design considerations through formal and spatial analytical parameters of space to think about autonomy, safety, and inclusivity through multiplicity in play space design to allow for space to be created through the act of play, rather than demanding for specified engagement.

Keywords Play space design · Government primary schools · Ergonomics · Play equipment · Children · Playful spaces

1 Play for Child Is No Child Play

All kinds of learning—emotional, cognitive, physical, and social—is accelerated, facilitated, and fueled by the pleasure of play. Conventional play space designs focus primarily on the organization [1], installation [2], and maintenance of 'manufactured'

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play equipment [3]. Play equipment criteria involves meeting typical safety standards [4] which compromises on optimum play possibilities that offers risk and challenge. It is seen that avoiding wear and tear often appears to be a bigger priority than the priority for the child's enjoyment. Hence, play is regulated, controlled and often restrictive for children. The purpose of the paper is not to oppose use of manufactured play equipment, rather to explore conceptual possibilities of creative integrated landscapes that cultivate a greater sense of place, with provisions for child enjoyment-hidden intangibles that connect children and play spaces. Playgrounds are, it is important not to forget, fun for children and if thoughtfully planned, this residual feeling of 'fun' after/during play will ensure lasting positive effects on their development. The factor of integrating safety and curiosity in its true nature is crucial in this phase of a child's development as this is that time when a child first stays away from the parent and has opportunity to learn as individuals. Hence, the question is, why not design for child recognizing them as individuals with special needs [5], according to what they call 'play' and what they conceive as 'play space' [6]. Opening an enquiry regarding 'what makes architecture playful', the paper offers design considerations through formal and spatial analytical parameters of space [7] to think about autonomy, safety, and inclusivity through multiplicity in play space design to allow for space to be created through the act of play, rather than demanding for specified engagement.

1.1 Body and the 'Self': Actions as Playful

Play antecedes culture [8] as something never taught or handed down. Emerging from sensorimotor activity, play, starts young. Driven by 'intrinsic motivation' [9] and innate curiosity, play, is an act that is autonomously performed by a child, who begins to discover multiple interactive possibilities, through a haptic engagement with its environment [10]. A child does not distinguish between play and other behavior unless and until, he/she/they, is/are made conscious of it. To an adult, play is often imagined as a realm that exists outside a system, which follows a certain discipline set by the society, to which they belong. These social systems are also responsible for creating certain ideas of what is appropriate behavior, language, gestures, taste, appearances, etc. [11] further defined by gender, class, caste, age, ability, etc.

The school a crucial institution, makes up one of these systems being built on a structure of knowledge, language, disciplinary actions, organizational hierarchies, gender hierarchies, etc. that are embedded within not only the curriculum but also in its everyday functioning to facilitating conducive learning environments [12–14]. However, something as natural as play, here, is often considered, 'a hidden curriculum' [15] that adheres to disciplines of set timings, allotted space, special equipment, or even supervised control. Play is therefore distanced from the sanctified formal education which is protected by an air of seriousness built around it.

But does play necessarily differentiate itself from the act of learning or work? If not, what makes an action playful and how does it impact the act of learning? While

work or the act of learning, starts with conditioning the 'self' of the child, to perceive the world through pre-established world views, play begins with the way the body locates itself in a space and explores around. It is through the body a child finds opportunity to exercise, express thoughts, and externalize his/her/their point of view. Through their actions they leave traces of their 'self' onto the physical environment which in turn through its sensorial expression imprints itself in the memories of the child. To play, therefore, is to be - to explore oneself or to even imagine oneself as multiple beings behind the mask of the body, therefore allowing for multiple identities.

Architecturally, many primary schools across India, including the case studies in Thiruvananthapuram, Kerala as analyzed in this paper, follow specific spatial requirements of spaces for programmatic distribution of the core areas of a school [16], and considers the circulation spaces like the corridors, toilets, staircases, the playground, etc., as peripheral spaces. Playgrounds are required to be demarcated, bound, fairly levelled, planted with trees - seen as large voids in school premises, where children position themselves relative to one another. Spatial and social hierarchies that are otherwise established by authority in the premises, are thereby challenged, wherein the spatial hierarchies are no longer planned spaces but temporally emerge out of the act of play itself. The child at play constructs or produces knowledge autonomously, through lived experiences, as opposed to having knowledge merely delivered to them. It therefore becomes imperative that the play space is designed to optimize and curate self-learning opportunities.

1.2 Play Space Design: Is Child a Measure?

Formalized, bound, and designated within an area and often play spaces are merely embellished with ready-made play equipment that follow certain standards of production, quality [1–4] which are claimed to be 'ergonomically designed' to stimulate child's play. However, the term 'ergonomically designed' is loosely used to describe something as being functionally 'good' [17] and if then functionality becomes the only criteria of design, the very complexities of its variations and ability to accommodate actions of different individuals, begin to cease.

Architectural standardization usually relies upon the discipline of Anthropometry, a branch of Ergonomics that deals with the measurements of the physical body and overlays it on parameters such as flexibility, mobility, strength and working capacity [17]. Guidebooks such as the 'Time Saver's Standards' and Ersnt Neufert's 'Architects' Data' have made multiple attempts of enquiring the 'most optimum' way of design, using the white male body as a measurement tool, leading to a range of measurements that are desensitized, reductive, exclusive, and indifferent to the variance in cultures, genders, age, and abilities. The same formula applied to an idealized child's body (refer to Fig. 1) whose still stature is used as the empirical underpinning of the anatomy of play space design. Ergonomics requires considering the body of the child, as a site of learning and trace stepwise actions of the child

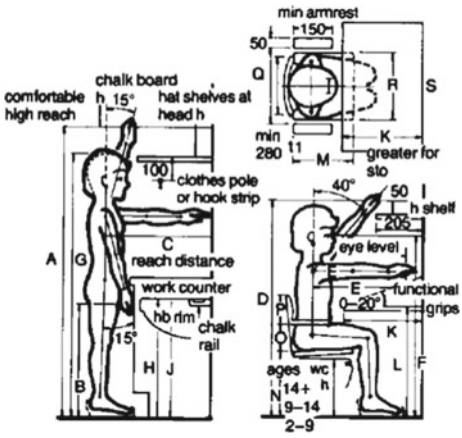

Fig. 1. Proportions of a child, measured and prescribed [18]

rather than making them adapt to a preempted manner of play that is usually expected of the ready-made play equipment.

1.3 Are Play Spaces Playful?': Looking at Case Studies

To determine the considerations for play space design, the paper examines spatial characteristics of four Lower Primary schools, namely, the Karamana LP School, Bhagvatipuram LP School, Vilappil LP School and Peyyad UP School, located in Thiruvananthapuram. These schools have students belonging to the age group of 5 to 8, a stage that Jean Piaget describes as the 'pre-operation stage' where children begin to develop both intuitive as well as symbolic thought that facilitate own points of view; where they associate real space with abstract concepts such as gestures, signs, words, and numbers. Children at this age also begin to create their own rules of action and movement [13] that largely define the way they play. The study involves qualitative analysis through observation and interaction with children through random sampling, during their play time, to map positionality by means of the planned core/peripheral areas of the school - built elements (elements built according to space), open space design and objects, in this case - prefabricated manufactured equipment – all of which be it fixed or movable, help determine the nature of the space as active spaces, spaces of solitude (individual), gathering spaces or experimental spaces [14].

Applying the theory of 'proxemics' [19] of intimate distance zones, the movement traces of 5–8 can range between 0.46 and 1.5 m during play, since it is a social activity. Considering area covered (πr^2), the total used space for a child can range from 0.66 to 7 m^2. This enables us to decipher the 'used play space' depending on available space as seen in Table 1 given:

Possibilities of Play- of Actions and Reactions: The case of Karamana LP School. The school has a legacy of over 125 years and yet, the play space (See Fig. 2a) is

Table 1. Showing used play space in the four lower primary schools

Name	No of children using the playground at a time	Play space area (in square meters)	Teacher: student ratio	Used play space after analysis (in square meters)	Rounded percentage of space used for play
Karamana	5	60	1:5	35	60
Bhagvatipuram	25	1087.5	1:18	350	20
Vilappil	20	478	1:10	280	30
Peyyad	34	68	1:10	68	100

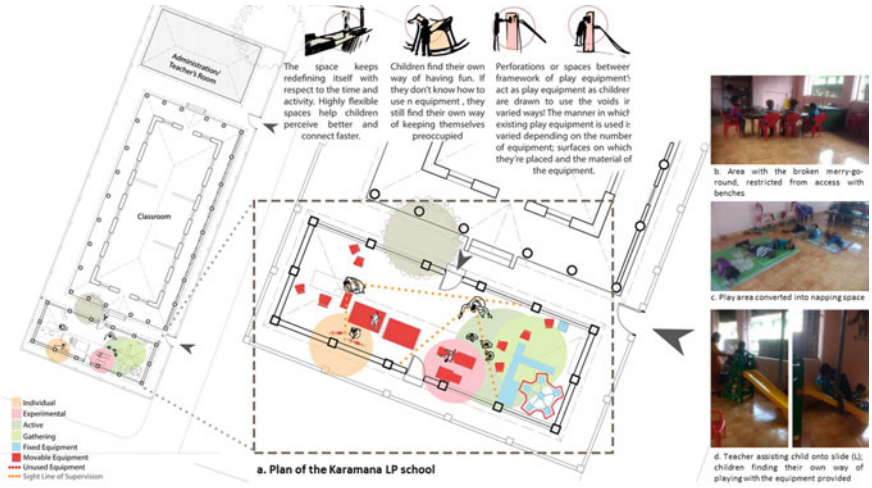

Fig. 2. Plan and activity mapping of the Karamana LP school

situated within an enclosed block, exclusively dedicated as a play space. Since the effective play space and play equipment available are limited, the children resort to solitary play by projecting changing play narratives, onto the objects made available to them. The act of play unfolds by finding the voids and crevices of the objects through intimate engagement and a subversion of the preempted intent allows the child to make new meanings around the use of the play equipment (Table 2).

Positionality of Play- of Spatial Relationships: The Case of Bhagvatipuram LP School. The play space area here (See Fig. 3a) is nestled within the school premises, and the play equipment provided to the rear side of the classroom, lay unused due to the difficulty of supervision in the area. As children are not allowed to play in the

Table 2. Mapping composition of the play space of Karamana LP school

Component(s)	Fixed/Movable [14]	Built element (B), Open spaces (O), Equipment (E)	Nature of space based on number of children using simultaneously [14]
High plinth	F	B	Inactive (0)
2 Wooden rocking horses	M	E	Individual (1)
Rusted merry-go-round	F	E	Inactive (0)
2 Plastic slides with side perforations	M	E	Experimental, Gathering, Active (4)

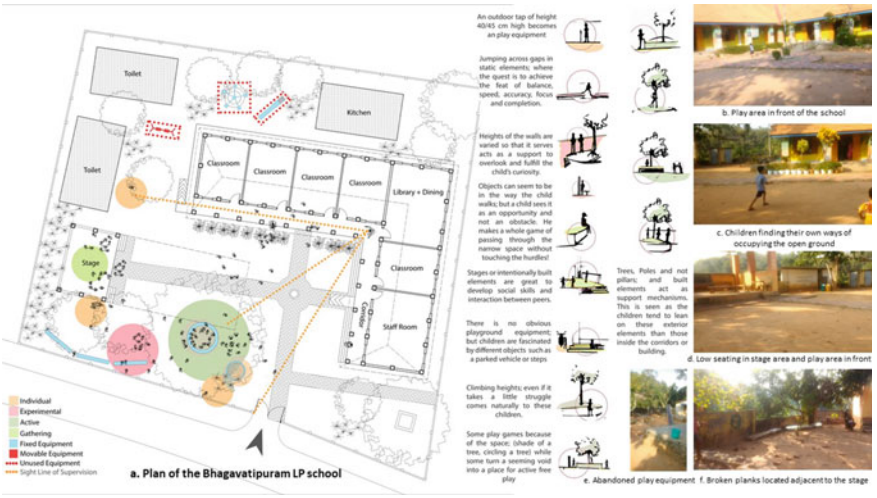

Fig. 3. Plan and activity mapping of the Bhagvatipuram LP school

rain or spend long hours in the sun; every child is conscious of the value of shade.[1] Here, shaded areas become prime nodes of exploration where play takes on multiple forms, from solitary play around smaller objects (mostly girls), to pair play in the more open areas, to group play around the tree and the stage areas where heights and level differences are a challenge and children tend to experiment (Table 3).

Permission to Pay- of Structures and Spatial Negotiations: The Case of Vilappil LP School. Here (See Fig. 4a), the central open space between designed building blocks is the designated play space, yet only the edges are shaded by trees and the shadows

[1] Based on interview of a 6-year-old girl (Name not mentioned for reasons of privacy), in which she mentioned that the students were constantly guided ad watched over by the teachers during play and never left their sight even if they played on the open ground beyond the shaded area. They would often be called back immediately if they went too far.

Table 3. Mapping composition of the play space of Bhagvatipuram LP school

Component(s)	Fixed/Movable [14]	Built element (B), Open spaces (O), Equipment (E)	Nature of space based on number of children using simultaneously [14]
Shaded plinth around tree	F	B	Gathering, Active (16)
Low heighted stage seating	F	B	Individual (1)
Tap near the wall	F	O	Individual (1)
Broken planks	F	B	Experimental (5)
Parked vehicles	F/M	O	Individual (1)
Rusted play equipment	F	E	Inactive (0)
Artificial pond	F	B	Individual (1)
Paved pathway	F	O	Inactive (0)

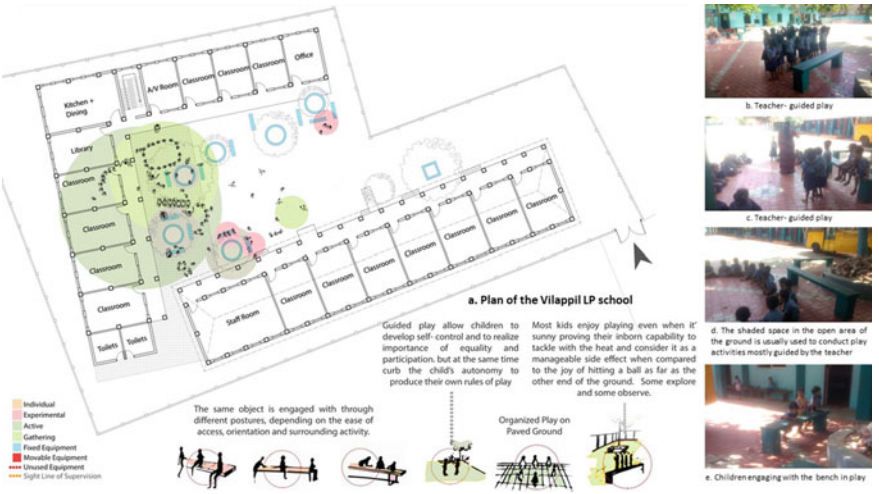

Fig. 4. Plan and activity mapping of the Vilappil LP school

of the surrounding buildings. Activity unfolds within the shade. Group play through 'Social contingency play', 'Physical activity play' and 'Language play 'are guided [20] - initiated and organized by the teachers who supervise activities with the intent of teaching the children to have fun while following rules of the game. The lack of play equipment and the supervision of guided play make some children attempt to create play around built objects such as fixed benches and the curbs around the tree and though these are built to a height that suit adults, children dare to use the orientation and form of the element to suit own body postures and activities (Table 4).

Table 4. Mapping composition of the play space of Vilappil LP school

Component(s)	Fixed/Movable [14]	Built element (B), Open spaces (O), Equipment (E)	Nature of space based on number of children using simultaneously [14]
Benches	F	B	Experimental (2)
Paved areas	F	O	Active, Gathering (14)
Hardscaped ground	F	O	Gathering, Experimental (3)
Tree curbs	F	B	Individual (1)

Postures at Play- of Imitation and Interaction: The case of Peyyad UP School. Here (See Fig. 5a), the gated play space is replete with play equipment of different types, and the children once they enter, are locked within. The irony of the need to enclose the space due to the expensive equipment added to the lack of circulation space and congestion which is more essential than for children to have fun, is what makes this play space a confined noisy cage with comparatively lesser potential to transform the play equipment to other forms of engagement. The availability of the equipment is not the determinant factor of playful spaces, but a heightened imitation of usage based on turns, risks and to a certain level; team coordination so that children can have fun through intense physical activity for the active participants. For the silent or the shy observers, the equipment become colorful supports (See Fig. 5f). Another noteworthy factor is the need for landscape as currently, it is through the wired enclosure, children observe and want to touch the plants growing outside showing the importance of natural elements as crucial as the play equipment arrangement.

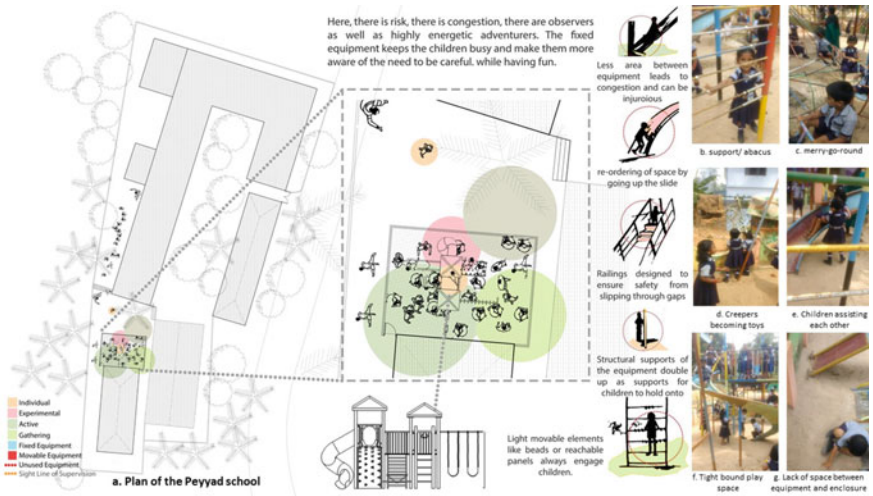

Fig. 5. Plan and activity mapping of the Peyyad UP school

Table 5. Mapping composition of the play space of Peyyad UP School

Component(s)	Fixed/Movable [14]	Built element (B), Open space (O), Equipment (E)	Nature of space based on number of children using simultaneously [14]
Merry-go-round	F	E	Experimental, Active, Gathering (8)
Playhouse	F	E	Active, Gathering (10)
2 Slides (Swirling and straight)	F	E	Active, Gathering, Experimental (10)
Swings	F	E	Gathering (4)
Net	F	O	Individual (2)

Table 6 Showing framework of ergonomics of play used to arrive at considerations

School(s) under consideration	Factor that allows for Multiplicity (Based on maximum frequency of use of play space)	Types of play	Multiplicity of structure of Play (RE – Repetitive FR - Fragmented, EX - Exaggeration, RO - Re-ordering)
Karamana	Movable equipment	SC, S, O	RE, FR
Bhagvatipuram	Fixed built elements	SC, P, FP	RE, RO, EX
Vilappil	Open spaces	SC, P, L	RE, RO, EX
Peyyad	Fixed equipment	P, O	RE, FR

The supervision ensures no tragic accidents, nevertheless, leads to enforcing a certain rule of using each equipment (Table 5).

1.4 Play as the Child's Measure of Space: Designing Architecture as 'Playful'

Based on the observations set out in the case studies that looked at the relationships between composition of play space and the nature of spaces to be 'playful', the following table enunciates the type of play as given below: SC - Social contingency play (contingent on one's behavior in relation to the other), S - Sensorimotor play (in a sensorial engagement with objects, O- Object play (construction using objects), L - Language play (speech, noises, words, cackles, etc.), P - Physical activity play (bodily movements such as kicking, running, etc., includes the sub-categories of rough play), and, FP - Fantasy/pretend play (one projects an imagined world onto the real world) [20]. Each case facilitates different types of play (Table 6) and deciphering this as well as the listing the structures of play, helps to evaluate play spaces through multiplicity

thereby forming the framework of the ergonomics of play that can be used to evaluate each play space composition.

Design considerations involves looking at what makes the architecture of play spaces playful through formal and spatial analytical parameters of space [7]. With regards to the child's play – it is then; not about presence of above components of play space, but becomes about where they begin/pause (Points of desire); what are they drawn to (Connectors); what play space can encompass of (Designing the void); how play spaces respond to adjacent spaces (Natural landscaping); and what makes play spaces playful (Methods of engagement/overcoming) detailed as follows:

Points of Desire: These points in the form of either fixed or movable objects are to be thought of as anchorage points in the overall narrative of play that forms the framework of the play space. These objects must be thought of as stimulating sensorially that urge a child to reach out for it, visually and physically. The use of colors, sound, light, shadow, and forms, designed to allow for a multi-sensorial experience. These objects should ensure freedom of movement through engagement of the body for its potential to be explored and allow to firstly establish familiarity and further multiple possibilities of experimentation which allow for a varied association (e.g. Figure 2d - use of slide by child in the Karamana LP School).

Connectors: Visual and physical connectors are required to tie together the Points of Desire to establish a language of expression. Visual language shall allow to establish a sense of familiarity with the place or even direct/ guide movement through the space. The connectors can also suggest different paths of movement to allow for a constant shift in perception of the space. This will further encourage a certain 'reordering' of movement within the space (e.g. Figure 3f – broken planks placed at distances in the Bhagavatipuram LP School).

Designing the Void: The void becomes essential to design, whether it may be a part of the object or a part of the larger play space as it is through the void, that the child will be al-lowed to move and explore, thereby develop their sensorimotor skills through multiple acts such as the act of sitting, jumping, twisting, turning, standing, leaning, grabbing, pulling, pushing, etc. those that allow for the child to learn to find equilibrium through their bodily postures. Voids can be designed based on proximity values so that by breaking the monotony, play is simulated and experienced through exaggerated moves (e.g. Figure 4e - Kid exploring possibilities of bench between paved shaded open space of Vilappil LP School).

Natural Landscaping: Extending an engagement between a child and nature becomes crucial as it allows for an exposure to diversity and a sense of timelessness. Planting of trees become essential to provide natural shade and initiate an intimate engagement with nature, as seen in each analysis (See Figs. 2, 3, and 4), shaded areas, rather than the planned paved areas are most active in encouraging in any kind of play that delves into individual fragmented observation and exploration that offers multiple layers of textures, forms, colors, shade and shadows, smells, sounds, of various species of flora and fauna, waiting to be unraveled (e.g. Figure 5d - Kid reaching up against

the creeper on the net to touch leaves outside the enclosed play space at Peyyad LP School).

Play Narrative and Methods of Engagement: To create play out of a void, would require strategic thinking and rules that define the method of play. Richard Sennett, suggests, rules of play are either set before the game, wherein the players become 'servants' to it or are devised through a sensorial experimentation of a body with/within a place. Many of these rules that are spontaneously devised may seem dysfunctional at first, however when a larger group is involved, a sense of consistency is achieved and become inclusive to accommodate players with different abilities [21]. With consistency comes repetition, one of the 'constituent behaviors' of playfulness, an act which is voluntarily repeatedly performed by a child on an object or in a space. Caroline Loizos further lists down 'fragmentation', which arises out of an exploration which is sporadic or partial to the actual use of the object or space; 'exaggeration', which arises out of emphasized movements performed by the child and 're-ordering', which involves the re-ordering of movements or activity, which has been otherwise assigned to a space, thereby challenging the spatial norms of a place [21]. The design, therefore, should have a conceptual framework to bind it that it allows for a more inclusive engagement when a larger group is engaged but at the same time, it should allow for the individual's imagination to manifest.

The Scope of Anthropometrics – a Method of Overcoming: As established earlier, a single child body cannot be used as a yardstick in determining the form of the object that is intended for many. The way in which each child uses an object depends on his/her/their bodily and behavior conditioning and is observed that in play, a child overcomes distances and heights through movement that requires them to think consciously, thereby contributing to their cognitive development. However, one may consider multiplicity of form, by repetition of a single element, changing only one parameter at a time, for example, the height, to provide a similar experience for children of different bodily measurements that in themselves are never a constant or consistent. As seen in the project 'ring around a tree' by Tezuka architects [22], which is a play space designed as a spiraling curved ramp with a gentle slope of gradient 1:25, with a railing height of 0.85 m built at different levels connected by steps of riser height of 0.15 m, which provides for a comfortable climb even for an average adult. The project uses a system of multiple mid-landings or mezzanines between the two main levels (first floor level at 2.104 and second floor level at 4.208 m) with a clearance height ranging between 0.6 and 1.5 m. The intention of providing such a variation is to allow for children different kinds of movement with the minimum height provided just enough for a child to crawl under. While even a height of 0.5 m can be a safety concern for children, gaining control and learning about these hazards become a part of a child's way of learning and understanding one's physical environment. Anthropometrics therefore can be considered while designing for voluntary conditioned movement, such as walking, climbing, grip around a handrail, height of a handrail/ parapet, to ensure safety, comfort and ease of movement while allowing for multiplicity of use and explorations when considered for play.

Rethinking of ergonomics of play as child's measure of space; rather than child as the measure in space with the above design considerations enables designers, architects, parents. teachers and people from all disciples irrespective of socio-cultural constructs to allow for play spaces to become playful extensions of the classroom, where the child's 'self' makes choices; regardless of supervision and the body enjoys in playful acts of repetition, fragmentation, exaggeration, and re-ordering in playful spaces – small beginnings that invest in prosperous futures.

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A Human Centered Approach to Redesign Prefab and Modular Bamboo Houses

Dipanka Boruah

Abstract Bamboo is one of the sustainable building materials in the world. Due to its durability, flexibility, low cost, lightweight, resiliency, easily cultivated and processed, bamboo is widely used. The building construction technique of bamboo is traditional and requires less time to construct. Bamboo along with metal can be used as a prefabricated (prefab) and modular building structure. The components of prefabricated houses can be constructed off-site, assembled and finished on site. Due to cheaper cost and time-efficiency, a prefab and modular housing system is the desirable strategy for quarantine center, isolation center, and temporary shelter for flood-prone areas. The aim of the research study is to redesign prefab and modular design houses using Bamboo material. The objectives include the study of traditional houses in Northeast India, different prefab and modular construction methods across the world, existing problems, physical properties of bamboo, treatment, and its uses. The methodology adopted for the study is divided mainly into three processes—Inspiration, Ideation, and Implementation. The Inspiration process includes a study from different works of literature of the concept of traditional housing, prefab structures, and different materials used with the HCD approach. Ideation includes the concept generation and ideas gathered and used in redesigning the prefab and modular bamboo houses. The initial Implementation or testing is done in the NID Assam campus and the performance analysis is carried and collected on the campus. This paper introduces a human-centered approach to the design and fabrication techniques of prefabricated modular bamboo houses, which can meet modern building requirements.

Keywords Prefabricated structure · Modular construction · Human centered design · Sustainable solution

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1 Introduction

Human centered design (HCD) is an approach for design and implementation of a solution which based other qualitative research of user's observations, needs and desires of people. While most of people are spending their lives within the built environment and social sustainability ahead of user well-being, comfort, and satisfaction. There is limited works of HCD approaches on construction techniques for house. Within the building construction industry, there are many construction methods those are: prefabricate and modular. Modular system in building means the modules that are built in an industry as partially finished, but that arrive on site and either that is placed or stacked. Modular architectural system has many benefits: (i) speed of erection, (ii) flexibility to allocate, (iii) cost effective, (iv) energy efficiency, and (v) low maintenance. The bamboo is very lightweight, flexible, tough, high tensile, cheap material as compared metal. It is a substitute for wood, cement, and other building materials as it is weather-proof and disaster-proof. A piece bamboo combines many nodes where transverse dipharm occurred between two nodes (Fig. 3b). Modular technique using bamboo is also an innovative and vernacular architectural system in the world. Bamboo has a demand in the construction industry to build architectural design due to its strength, durability and aesthetic value. In addition, structural properties of the bamboo is its strong fiber, which double compressive strength of concrete and conceptually the strength- to- weight ratio of steel in tension [1]. On the other hand, prefab means the system such as panelized system, prefab component that are built within the industry and arrive on-site ready to put together. An example of prefab method is Airship Hangars in Orly, France which was made of prefab repetitive concrete arches and massive enclosure allowed for the storage [2]. Prefabs are typically used in large-scale affordable housing or where on-site construction is difficult [1]. Now a day people is expanding its use to different geographical locations such as public infrastructure and roads. Prefab houses have been installed to build new hospital and quarantine centers through the covid-19 pandemic. Prefab construction is much faster than traditional construction because various functions can be completed simultaneously in the same duration [3]. The Sustainable Materials Lab, NID chooses to take up the challenge of designing bamboo made prefab and modular house as a quarantine facility in the campus within the short period. Emphasis was on creating design intervention by using locally available materials with the help of prefab and modular fabrication method.

2 Literature Studies

2.1 Traditional Houses in Northeast India

There are three types of bamboo houses in Northeast India. They are (i) Ikra is called Assam Type House (Fig. 1a), (ii) Mud House (Fig. 1b), and (iii) Chang House (Fig. 1c)

(a). Ikra house (b). Mud house (Andharia, 2020) (c). Chang house

Fig. 1 Traditional houses in Northeast India

[5]. Ikra House are easy to construct, maintain and economical. The construction method is a frame structure which consists of vertical component (wall) using bamboo and wood frame. The walls are covered with mud and cement plaster. The roofs are covered with galvanized iron (G.I.) sheet. On the other hand, longevity of mud plater house is too short. It needs to be replaced once every two years due to wear off with lashing rain. In addition, the concept of Chang House was adopted by the Himalayan civilization but due to heavy rainfall in Brahmaputra river valley, people have widely accepted this stilts form of construction. This house has two parts, lower part is used to provide shelter for domestic animal and upper part is used for habitual space.

This house has two parts, lower part is used to provide shelter for domestic animal and upper part is used for habitual space. This stilt structure also helps in protection from wild animal as well as flash flood in the bank of river Brahmaputra.

2.2 Prefab and Modular Construction Method in Building

The history of prefab construction house has more than 300 years of in the world. The first component of prefab component of building were manufactured in 1624 and those shipped to the fishing village of Cap Anne in Massachusetts, USA [6]. Prefab construction method consists of many factory built components which are assembled at the site to construct the overall unit [2]. Modular, panelized and precut construction are included under prefabricated construction. This method of construction has brought a major change in the development of construction industry. It ensures the economy, strength and environmental performance of the structures [7]. All prefab and modular houses are showing in the Fig. 2a–f [8–13].

Similarly, a modular building can be constructed more than fifty per cent of faster than traditional construction methods [14]. It can be more affordable than on site building and shorter time consuming. A young designer from Manila developed a special modular housing model called ‘Cubo’, which solves housing models in the Philippines. This housing model can be constructed within four hours [15].

Fig. 2 Various prefabricated and modular houses in the world

2.3 Physical Properties of Bamboo

The physical characteristics of bamboo are hollow woody plant belongs to a grass family, the scientific name is Gramineae and sub family is Bambusoideae [16]. There are fifteen hundred bamboo species all over the world, Bambusa balcooa, Bambusa tulda, Koko bamboo, Mokalm bamboo etc. are the most usable bamboo species among them [17]. They are found across Asia, Africa and America and the percentage of 65, 28 and 7 respectively as shown in Fig. 8a. The morphology of the bamboo plant consist of branches, sheaths, culms, flower, leaves, rhizomes, and roots are stated in the Fig. 3b [19].

The mechanical properties of bamboo are mentioned below:

- Résistance to external forces. This force depends on the magnitude and manner of loading i.e. tension, comparison, shear, bending etc.
- It has wonderful tensile strength. Bamboo are closely correlate with specific gravity and density.

The mechanical properties of bamboo are correlated with specific gravity and density. The strength and stiffness of bamboo culms compared with other building materials. In the Table 1 [8], the strength and stiffness increases with specific gravity.

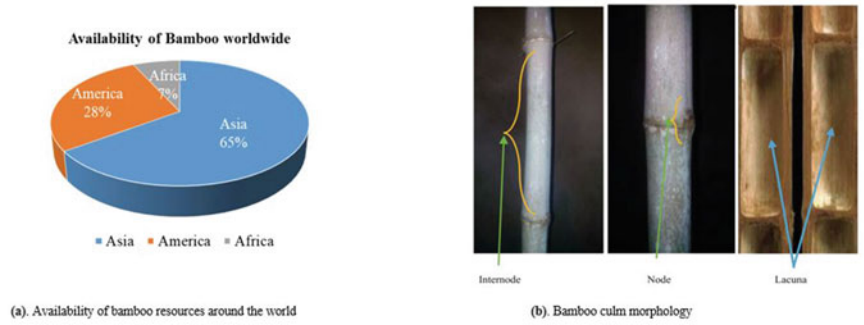

Fig. 3 Physical properties of Bamboo

Table 1 Comparing the efficiency of materials for strength and stiffness

Material	Strength (Nmm-2)	Weight by volume	Ratio	Stiffness (Nmm-2)	Weight by volume	Ratio
Concrete	8	2400	0.003	25000	24000	10
Steel	160	7800	0.02	210000	7800	27
Wood	7.5	600	0.013	11000	600	18
Bamboo	10	600	0.017	20000	600	33

* Ratio = strength or stiffness/weight by volume

2.4 Raw Bamboo Treatment Methods

Treatment of bamboo is a very important stage to increase its longevity and protects from termites and insects. In addition, the process is to increase the dimensional stability and retain strength, fire resistance, improve aesthetic quality. In this process need three main materials: Borax or sodium borate with water ($NA_2B_4O_2.10H_2O$), Boric acid (H_3BO_3) in (1:1.5) ratio. The treatment process can be done through various conventional methods such as traditional or nonchemical treatment methods, which are for clump curing, water soaking, and fire (smoking) treatments (Fig. 4) that followed by indigenous people but the effect of these treatments is limited. In culm curing method, fresh and matured bamboo culms along with leaves are stored in shaded place for 10 days to 25 days and in this process bamboo, culms discharge starch contents due to respiration in tissues and leaves. Thus, this method is always used before utilizing the bamboo (Fig. 4a). In Asia and South America, a common method is diffusion or soaking method (Fig. 4b) whereas harvested bamboo poles with high moisture content (above 50%) are either submerged or running water with stones on top of them for 10 to 20 days in diffusing of the starch, sugar and other active water soluble ingredient [20]. However, the process using smoke to prevent insects from the bamboo. The bamboo can be stored above the fireplace and bamboo culm will blacken. The effect on durability is limited (Fig. 4c) [21].

Fig. 4 Traditional treatment method for harvest bamboo

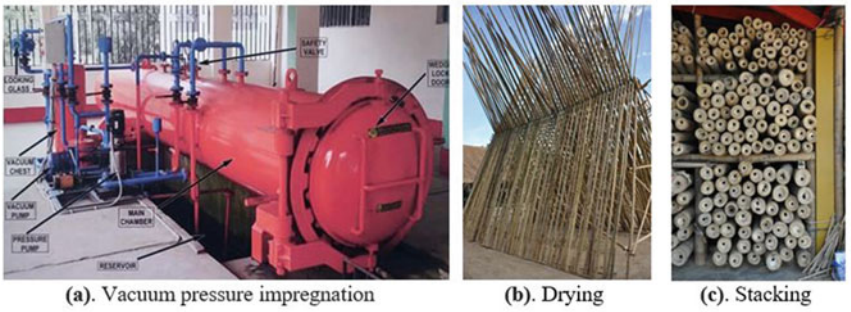

Fig. 5 Vacuum pressure impregnation treatment for bamboo and drying

Besides a custom design equipment to treat bamboo chemically, which protects a harvest bamboo from fungi, bacteria and other insects is called as vacuum pressure impregnation treatment for bamboo. A technical parameter is prepared during the treatment process of bamboo in the equipment shows in the Table 2. After putting the harvested bamboos in the equipment, the borax with water ($NA_2B_4O_2.10H_2O$) solution is impregnated deep into the pores of bamboo with help of vacuum and pressure (Fig. 5a). Once the bamboo poles are chemically treated, bamboo are kept for air drying in direct sunlight in a prolonged time (Fig. 5b) about 7 to 30 days.

Table 2 Technical parameters as in vacuum pressure integration treatment plant for bamboo

Sl. No.	Description	Unit
1.	Size of the cylinder (main chamber)	Dia-3′6″ and Length-22’
2.	Capability of cylinder for withstanding vacuum	650 mm Hg
3.	Creating maximum pressure	14 Kg/cm^2
4.	Loading and drilling time	30–45 min/cycle
5.	Vacuum time	15–25 min
6.	Pressure time	80 min
7.	Discharging time	20 min

Later the bamboo poles are left to dry slowly in a shaded and dry place until they are used for bamboo construction (Fig. 5c).

3 Methodology

The research focuses on necessity of post disaster infrastructure, quarantine center for pandemic, isolation center for hospital, and temporary shelter for flood-prone areas in developing country like Northeast India. Tim Brown of IDEO (a global design and consulting organization based in California) argues in this case about how to design for change, what needs a new idea, and how to build a house that is less expensive and time-efficient [22]. His proposal belongs to a three phased process: *Inspiration, Ideation and Implementation* that process is called Human Centered Design. A HCD approach solves when a problem does not exist abstractly in a society, but there is always from some's suggestion of scenario on people need. However, Norman [23] defined in his book titled The Design of Everyday, HCD as an approach that puts human needs, capabilities, and behavior first, later designs to apply those needs, capabilities, and ways of behaving [24].

4 Contextual Study

A pilot study was carried out to find out shortcoming scenarios of rural, semi urban and urban areas in India. Low-cost housing settlement are affected by floods created by the river Brahmaputra, Barak and other small rivers in Assam. Flood victims use a banana raft to get from their submerged home to higher ground (Fig. 6a) [25].

In the Fig. 6b, a doctor checking a patient's health status and real scenario of Covid-19 pandemic in Uttar Pradesh, a person having oxygen and sitting on street bench (Fig. 6c) [26]. Literature survey of various factors associated with people health and lifestyle were carried out. The temporary shelter for the healthcare facilities, disaster

Fig. 6 Contextual studies of flood affected, open house medical check-up and worst Covid-19

resilient house and quarantine or isolation center for pandemic situation. The shelter can be operated as another activity after completion of earlier activities.

5 Design Brief and Formulation of Design Problem

Based on observation during the field visit and discussion with people, it will be viable and socially acceptable using locally available vernacular materials and having consideration of social sustainability. During the observation, it has been found that there are many challenges with existing traditional construction houses such as unavailability of skilled labor. Therefore, people do not prefer to construct the bamboo house easily in a short period of time as a temporary purpose. In addition, the jointing system is very difficult and complicated in bamboo. The Fig. 2a shows the construction techniques of modular house in India are metal framed structure with bamboo mat board walling and whole framed structure rests on raft foundation. For constructing of framed structure it is required to use welding machine with skilled manpower. Also the metal framed structure does not carry on a truck without dismantling the metal framed structure.

Need of current practice on the redesign and development of prefab and modular house in hospital, highland, bank of river as quarantine center, isolation center and temporary shelter for flood affected areas in Assam, Northeast India. In this regard, a design proposal was proposed to solve for these people in India.

- Substituting brick, wood, steel and cement, bamboo reduces up to 40% and constructing walls, floor, and roof with other alternative materials.
- Cost reduction by using prefabricated components, increasing the speed of construction.
- Low cost and easy to assemble solution.
- A unit can be constructed within 4 to 5 hours.
- Design parameter based on anthropometry and ergonomics standard.

5.1 Concept Generation

The feasibility study was carried out in NID Assam campus for making of Covid-19 dispensary cum quarantine center for the students. The initial sketches were prepared (Fig. 7a–e) to create the next stage of conceptualization. The design maximizes the use of traditional bamboo building techniques, prefab for the walls and solar blinds. The roof provides shade and offers protection from heavy rains.

Based on shortcoming existing prefab and modular houses (Fig. 2a–f), new concept was created. Previous examples of houses are very heavy which was made of concreate, metal and wood. Thus, houses cannot be carried to install. A temporary modular housing is removal structure that is located on a site for a limited period

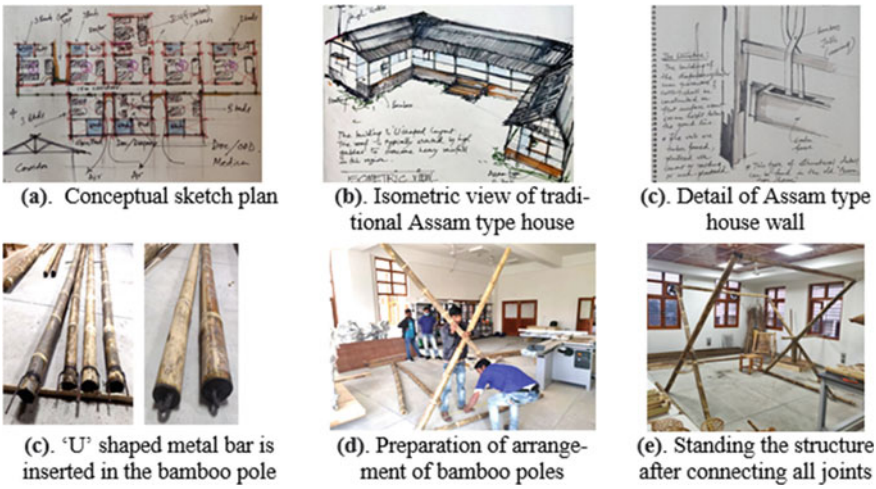

Fig. 7 Temporary shed for dispensary in NID Assam campus

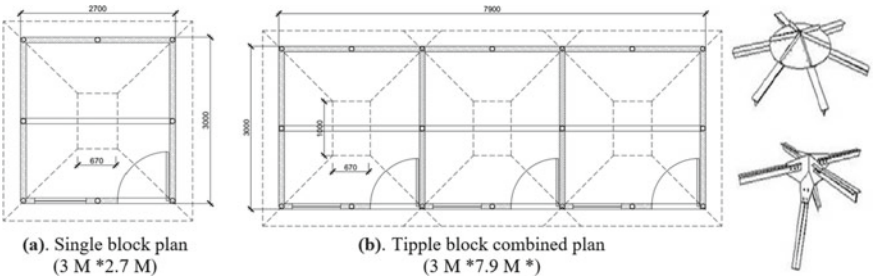

Fig. 8 AutoCAD 2-dimensional plan of prefab and modular house and roof connector

and this is used as a relief shelter and sometimes it can be relocated to multiple sites over time.

Therefore, it should be substantial for re-use. In addition, development of temporary modular housing provides facilities are as follows:

- Two nos. of bed, one table where a gas cylinder can put for cooking, one wardrobe for keeping goods.
- Strong metal connector arrangement is to be fixed for the expansion of units.
- Provision of safety and ergonomic comfort and protect the user from nature.

Two-dimensional CAD modelling was prepared to better understanding of space arrangement and utilities is shown in Fig. 8. The dimensions of a single unit area are 2.7 m × 3.0 m (Fig. 8a) and triple combined block plan of single blocks as detailed components are mentioned in Table 3.

Table 3 Different types of metal component for assembling the prefab and modular house

Component's name	Metal components	Size (L*B*H)	Weight (in Kg approx.)	Requirement (Single unit)
1. Foundation		400 mm *400 mm *400 mm	15	4 nos
2. Column connector		150 mm *75 mm	1.5	4 nos. It is screwed with foundation
3. Corner joiner		200 mm *200 mm *400 mm	6	Total 12 nos. 4 nos. each for plinth, lintel, and roof
4. Wall combiner		200 mm *200 mm	4	Total 12 nos. 4 nos. each for plinth, lintel, and roof
5. T- joint		200 mm *200 mm *200 mm	8	Total 2 nos. 1 no. each for plinth, lintel, and roof
6. S.S. Nut bolt		100 mm *70 mm	0.25	Total 24 nos. 2 nos. each for corner joiner
7. Modular connector		400 mm *400 mm *400 mm	10	Total 3 nos. each for edge of wall while modular house is joined

5.2 Process of Manufacturing of Various Component

The various metal components were (shown in component 2, 3, 4, 5, 7) manufactured individually since craft process like local blacksmith and welding. The size of those components were made as per the standard size of bamboo using jigs and fixtures. Balcooa bambosa and Balcooa Tulda were used for assembling of the house.

Pad foundation is off-site construction technique that was casted before putting into excavation in the earth. Due to cost reduction, time saving, increases of productivity, quality and safety thus this technique is used. The Table 3 gives a detail of components of the structural members.

5.3 *Prototyping of Redesigned Prefab and Modular House*

Initially CAD modeling (Fig. 9a) was carried to obtain digital data of house. The installation-planning phase for the house involves multiple steps. The preliminary design of this type of house was intended to establish an overall concept for the project and served as guideline for detailed design. As a first step in preliminary design, an attempt was made to redesign and develop a modular house suitable for temporary establishment with due consideration for anthropometric aspects, safety, sustainability and environment friendly. During the design of individual metal, concrete components, along with subsystem connectors (Fig. 9c) of bamboo pole in relation to fit in overall arrangement needs to be considered, its surface treatment with the components. The eight bamboo poles were lashed together to create pyramidal shape of roof structure (Fig. 9e) was placed upon eight vertical bamboo poles where metal components were assembled and those four corner columns were screwed with precast pad foundation (Fig. 9b). In this regard, overall progress has been made in components design through systematic engineering method such as finite element method. Bracing system is applied to prevent shaking and to provide strength to the structures. Bamboo plank are to be used as flooring that will strengthen the superstructure from wind pressure (Fig. 9d).

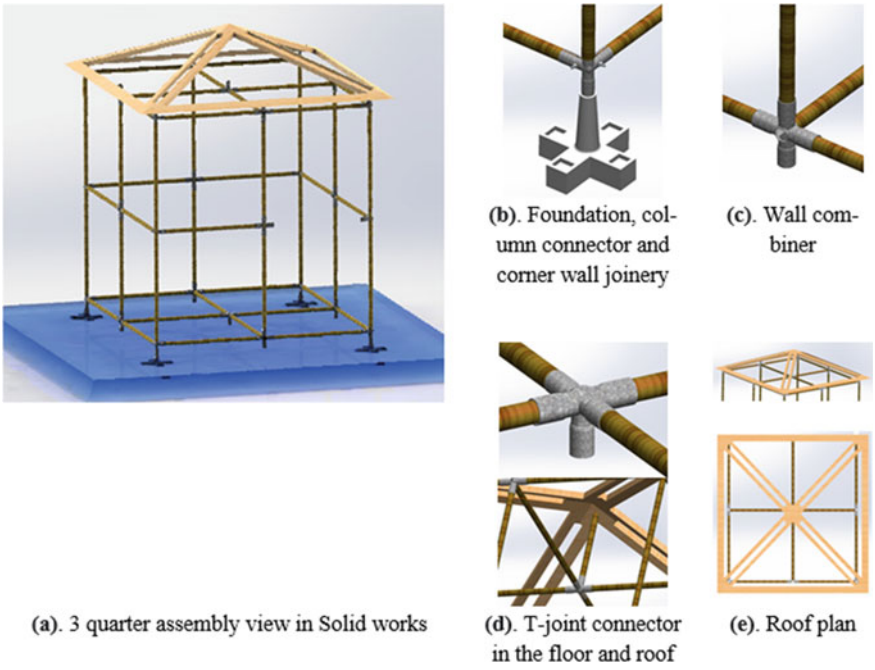

Fig. 9 CAD model and details of assembly model

5.4 *Anthropometrics Parameters on the Newly Designed House*

The newly designed house is considered as the 95th percentile anthropometrics data. CAD detail dimensions of a single block is 3 m length, 2.7 m breath where two single beds fit alongside of left and right direction. However, 0.6 m gaps between two beds where someone can move easily. In addition, one wardrobe fits in a single block. The dimension of door is 2.1 m $\times$ 0.9 m as standard anthropometric standard for architectural house. Single window is placed between two beds which is 0.9 m sill height from the floor level.

6 Conclusion

The research work was aimed a need to redesign prefab and modular design with Indian context. The conceptualization of this house followed in this research work would enhance with the HCD approach. The use of this house using bamboo panels along with metal components facilitate the assembly of structure with respective jointing systems. In this regard, preliminary test on the metal joints with bamboo sub structures are completed in NID Assam campus and performance feedback from artisans and workers has been collected. These houses are designed to showcase improvements to the prefab, modular along with traditional materials to server as models for the future housing concept, temporary shelters such as isolation home for pandemic and other contextual scenarios. The performance feedback, safety and durability and ergonomics design analysis in an actual site will be carried out in the future work.

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Ergonomic Risk Assessment of Office Workers in a Consulting Firm in Kerala

A. A. Nikhila and R. Rajesh

Abstract Office workers often develop work related musculoskeletal disorders (MSD) in lower back, neck, upper and lower extremities. The study methodology includes systematic procedure to assess risk of MSD, analysis of office layout for environmental stress factors, digital human modeling for workstation design. The study identifies the prevalence of MSD and ergonomic risks among employees of a reputed environmental consultancy firm in Ernakulam district in the state of Kerala, India. The study sample comprises of all office workers in the firm. Preliminary data on MSDs was obtained through a questionnaire survey ($n = 26$). All the participants had MSD symptoms with back and lower body parts, and neck and upper limbs problems. 70% have experienced MSD symptoms in the last six months. Ergonomic assessment protocol includes video recording of tasks and workstations, comfort measurement through questionnaire, workstation assessment by ROSA tool and measurement of environmental conditions such as temperature, sound, light and ventilation. ROSA assessment indicated the need for workstation redesign. Assessment of environmental conditions indicated the need to improve lighting, temperature and ventilation condition. RULA analysis of existing workstation using digital human modeling indicated various workstation issues. Further work includes ergonomic redesign of workstation and workplace for the consulting firm.

Keywords Work related musculoskeletal disorders · Office ergonomics · ROSA · Ergonomic design · Workstation · Office layout

1 Introduction

Office ergonomics is a key guide to equip employees at the workplace to produce better performance. To meet the ergonomic requirements, design of workstation along with appropriate work place layout is important. Poorly designed office contributes to the development of various musculoskeletal disorders amoung office workers. Ergonomic risk assessment methods examines the worker's movement, effort and

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body position to determine the risk factors that contribute to the development of MSD.

Workplace comfort assessment often involves assessing the physical work environment such as workspace dimensions, ventilation, noise or lighting conditions. Consideration of workstation and workplace aspects can lead to better ergonomic redesign of office space.

This study focuses on ergonomic redesign of an environmental consultancy firm GME in the state of Kerala, India. The sub-objectives of this work include ergonomic risk assessment of office workstations, workplace comfort assessment and ergonomic redesign of high risk workstations and office layout. The contents hereafter are organized in three key sections i.e., methodology section highlights the study procedure, results section highlights on fieldwork and the accompanying discussions and finally the conclusion section looks at the summary, conclusions and recommendations emerging from the work.

2 Literature Review

An office space consists of chair and workstation, keyboard, mouse, monitor, office lights, office spatial, environmental conditions. The literature review on office ergonomics is organized into three sub-sections i.e., musculoskeletal disorders among office workers, ergonomic risk assessment tools, ergonomic design of a workstation and ergonomics intervention.

2.1 Musculoskeletal Disorders Among Office Workers

Office workers such as bank employees, insurance office workers, Software developers develop MSDs over a period of time. MSDs are injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs. Office workers develop MSDs on their upper body parts such as shoulders, arms, elbows, wrists, hands, and lower body parts such as back, legs and feet [1, 2]. They are caused by forceful or repetitive movements or a poor operating posture. Symptoms embrace tenderness, aches and pains, tingling, stiffness and swelling. Lower and higher back pain arises from long sitting and excessive leaning. Repetitive action from typing, keying and sorting operations causes cumulative trauma disorder. The area's most frequently affected by CTD are the tendons, muscle, and nerves of the upper extremities and torso. One of frequently used tool to record MSD prevalence is Nordic Musculoskeletal Questionnaire [3].

2.2 Ergonomic Risk Assessment Tools

The risk in work-related MSD can be quantified using different ergonomic risk assessment tools. Some of the observational tools used for ergonomic analysis of physical work include Ovako Working Posture Assessment System, Rapid Upper Limb Assessment, Rapid Entire Body Assessment, Quick Exposure Checklist, National Institute for Occupational Safety equation [4, 5]. The tools used for assessing office work include Rapid Upper Limb Assessment, Office Ergonomic Assessment tool, Quick Exposure Checklist, Strain Index and Rapid Office Strain Assessment [2, 6, 7].

Rapid Office Strain Assessment (ROSA) tool is designed to quantify the risks of work related to computer usage at a computer workstation [6]. ROSA utilize graphical portrayals of postures that relate with a risk score intelligent of the general probability of the posture causing a musculoskeletal problem In ROSA there are four sections of score charts i.e., Office Chair, Monitor, Keyboard, Telephone and Mouse. The total score is obtained by scores obtained for the individual risk factors. The ROSA score ranges from 1 to 10. A higher ROSA score indicates an increased risk for work related musculoskeletal disorders. Based on the ROSA score the action level is decided.

2.3 Ergonomic Design and Ergonomic Interventions

Ergonomic training programs to provoke activity changes, postural changes and workplace exercises are commonly used to reduce and mitigate MSD issues. Ergonomic design of work station using digital human modeling (DHM) tools has become part of ergonomic interventions in practice. DHM is an approach in which the ergonomic dimensions could be considered at the very early stages of the design development and an idea could be obtained on how the end user would be affected by the design. DHM can be created in software such as MannequinPro, Safework, Sammie, Jack, Santos, 3DSSPP, Delmia and Technomatic [4]. Ergonomic tools in these software permits users to research and predict human safety, comfort level, and performance for targeted populations inside the 3D virtual surroundings through various ergonomic analysis techniques. DHM has been used for ergonomic design of office work systems [8]. Work station redesign and modification of workplace layout comes under physical ergonomic intervention. Many studies have indicated that changes in workstation and work environment results in employee's satisfaction, reduces absenteeism, comfortable and safe, reduced MSD issues, improved productivity [9–13].

3 Methodology

The study is done in an environmental consultancy firm in Ernakulam district of Kerala, India.

3.1 Data Collection

The target population for this study was the entire staff and management of company. This includes 26 employees from the various functional departments and units at company, while excluding security officials, casual workers and field workers A questionnaire was used to collect demographic details, task details and MSD information. This was followed by the use of observation technique ROSA. Photographs and video recording of various tasks were undertaken. Direct measurements of environmental variables such as temperature, sound and light were recorded.

3.2 Tools Used and Procedure

A questionnaire was used for recording task details and MSD prevalence. For risk assessment of work station ROSA is used. Postures and working environment is checked for each aspect of office work i.e., sitting on chair, use of monitor and telephone, mouse and keyboard. Scores are recorded for chair, monitor, mouse, keyboard and telephone in the ROSA sheet [6]. The action levels are decided from the ROSA score.

For mapping comfort settings of the office environment a 5-in-1 multi-function environment meter is used to measure sound levels, light levels, airflow, %RH and temperature. The luminance measurements were carried out at three heights i.e., at 20 cm above the ground, at 80 cm above the ground and at 110 cm above the ground. Thermal measurements were taken near window, entries, corner and centre of room space. Radiant temperature and air velocity was measured at 10 cm, 60 cm, and 110 cm for seated occupants from ground level. Comfort parameter for quantitative assessment of lighting characteristics is obtained by Eq. 1 and temperature is obtained by Eq. 2.

$$U_R = \frac{Eh_{min}}{Eh_{avg}} \tag{1}$$

where

Eh_{min} is the minimum luminance and

Eh_{avg} is the average luminance.

$$t_0 = \frac{(t_{mr} + \left(t_a \times \sqrt{10v}\right)}{\left(1 + \sqrt{10v}\right)} \tag{2}$$

where

v is air velocity

t_a is air temperature, t_{mr} is mean radiant temperature,

t_0 is operative temperature.

For the redesign of critical work station digital human manikins are created by customizing inbuilt population in CATIA V5 human builder module. The current workstation is modeled and RULA analysis is done to identify key workstation issues. Details of RULA can be found in [14].

4 Results and Discussion

The office workers had an age of 32 years (SD = 7.5), weight of 59.6 kg (SD = 6.5), and height of 162 cm (SD = 11.3). The work force consisted of 70% Female and 30% Male. The average length of service in the firm was 4.3 years. More than half the office workers have availed sick leave during their service, and more than one third of them complained of muscular discomfort often. An enquiry on MSD issues in body parts of the employees in past six months revealed that neck, back and lower body and head were the body parts of concern (Table 1). MSD analysis of employees indicates that office workers continuously suffer from some kind of MSD.

4.1 Ergonomic Risk Analysis

The office workers were observed to be working mostly in the sitting position in the office. Each workstation were equipped with desk, chair, computer and telephone. The postural activity on computer work and answering the telephone were the ones that needed attention. The mean ROSA score obtained for different sections and total ROSA score are presented in Table 2.

Table 1 Observed prevalence rates for MSD

Body part affected	Occurrence in last 6 months (%)
Neck	57
Upper limb	13
Back & lower body parts	52
Head	43.5
Sensory parts	26

Table 2 ROSA score for each section

Section A—chair	Mean score
Chair height	2.92
Pan depth	2.58
Arm rest	2.83
Back support	3.75
Duration	1.00
Section B–monitor & telephone	*Mean score*
Monitor	4.83
Telephone	3.00
Section C–Mouse & keyboard	*Mean score*
Mouse	3.58
Keyboard	5.25
Sections	*Mean score*
Section A	7.83
Section B	6.00
Section C	7.50
Final ROSA score	8.60

The ROSA score for chair is 2.92. Examination of the worker posture revealed that most of the workers had the chair height with the knees too low i.e., knee angle less than 90º and there was no sufficient place under the desk to cross legs. Pan depth was less than 7.6 cms, and was not adjustable. The arms are unsupported, causing elevation of shoulders. Also the armrest was not adjustable. The chair did not provide adequate lumbar support, and majority of workers were leaning forward for doing the tasks. The work surface height was higher therefore the workers shoulders were shrugged during accomplishing their task. The back support was not adjustable. As the workers were in seated posture for more than four hours daily, highest score was assigned in the ROSA sheet. Maintaining a posture of sitting during long hours in static postures causes inadequate muscular activity. The monitor position was 30º below sitting eye level. The workstation did not have proper documents support. This causes frequent flexing and rotation of neck by the work, and often the neck twist was observed to be greater than 30º. Workers often were seen to adopt an awkward posture of the neck while using telephone i.e., holding the phone between their head and shoulder. The workers use of mouse indicated non alignment of wrist with the shoulder resulting in shoulder abduction. It was observed that mouse and keyboard were located at different surface levels in most of the workstations. The office work demanded an extensive use of mouse for long periods of time. The office workers were observed to use the keyboard with their wrists extended. The platform were keyboard is kept was not adjustable. The final ROSA score was 8.60. This indicates that workstation pose MSD risk, and that it requires investigation of the workstation.

Table 3 Indoor environmental quality measurements

Parameters	Maximum	Minimum	Average
Lighting (Lux)	100	75	92
Temperature (°C)	32.2 °C	31.3 °C	32 °C
Air velocity (km/hr)	0.15	0.1	0.15
Humidity (RH)%	65	63	64
Sound (dB)	70	66	67

4.2 Comfort of Employees and Office Layout

The environment measurements on temperature, lighting, sound, air flow and humidity are presented in Table 3. It is observed that the average lux value of 92 is less than the 150–300 lx recommended by Occupational Health & Safety Administration (OSHA) for a standard office room. Therefore, existing lighting conditions should be improved. Comfort parameter for quantitative assessment of lighting characteristics is obtained by Eq. 1. The lighting uniformity value obtained is 0.82. Since this value is better than the CIBSE recommended range 0.6 to 0.8, it can be inferred that the lighting uniformity is acceptable in the office. For air velocity up to 0.2 m/s, Eq. 2 is used for calculating operative temperature. Accordingly t_0 is obtained as 32.11 °C. The acceptable range of operative temperature according to ISHRAE is 24.5 ± 2.5 °C for office buildings during summer cooling season. The sound level of 67 dB is below the 85 dB recommended for a 8 h duration by National institute for Occupational Safety & Health. Therefore the sound level is acceptable in the office. The humidity value 64% is acceptable as per, but the air speed of 0.15 km/hr is low. The average temperature of 32 °C is above the OSHA recommended temperature range of 20–25 °C. Therefore, increased ventilation and temperature control is required. Overall, there is a need to improve lighting, temperature and ventilation condition in the office.

A survey was conducted to find the relationship between indoor environment and satisfaction of employees. Table 4 indicates the level of comfort and discomfort on different workplace variables. More than half of the office workers were not comfortable with the temperature condition. The need for better temperature control and ventilation has been highlighted through our analysis from direct measurements.

The worker's response indicated scope for improvement in layout attributes such 'Workplace orientation', 'Availability of free space', 'Access to equipments' and 'Workplace separations'.

4.3 RULA Analysis in Existing Workstation

Figure 1 shows the measurement of existing chair and Table. The anthropometric parameters in DHM are body height, sitting height, shoulder height, popliteal height,

Table 4 Level of comfort and discomfort on different workplace attributes

Attributes	Comfortable (%)	Acceptable (%)	Not comfortable (%)
Lighting condition	26.1	73.9	Nil
Temperature	17.4	30.4	52.2
Availability of free space	26.1	43.5	30.4
Orientation of workstation	43.5	39.1	17.4
Visual comfort	26.1	65.2	8.7
Access to office equipments	21.7	69.6	8.7
Work place separation	34.8	47.8	17.4

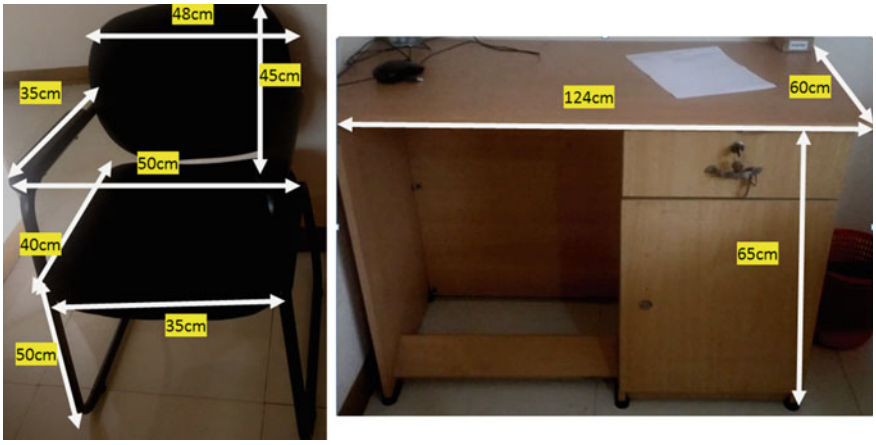

Fig. 1 Existing chair and table with dimensions

hip breadth, elbow height, buttock-popliteal length, buttock-knee length, thigh clearance, eye height, shoulder (bideltoid) breadth, body mass (weight). Figure 2 shows human mannequin in sitting posture in CATIA V5.

RULA was used for posture analysis of existing workstation. Data such as posture, load borne by the limbs, frequency of the moves and the directions were recorded in relevant sections of the RULA tool. As the move was greater than 4 times a minute, "repeated" option was selected. Arm support was added and the load was specified to be zero. Figure 3 shows the RULA scorecard of the human digital model in existing workstation posture. RULA final score of 6 indicates the investigation is needed and that change is required.

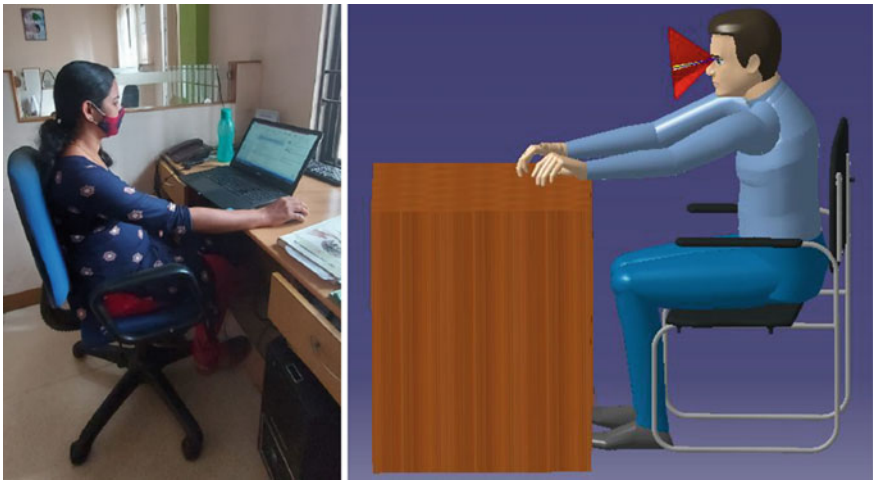

Fig. 2 A sample workstation in office and DHM model of a workstation

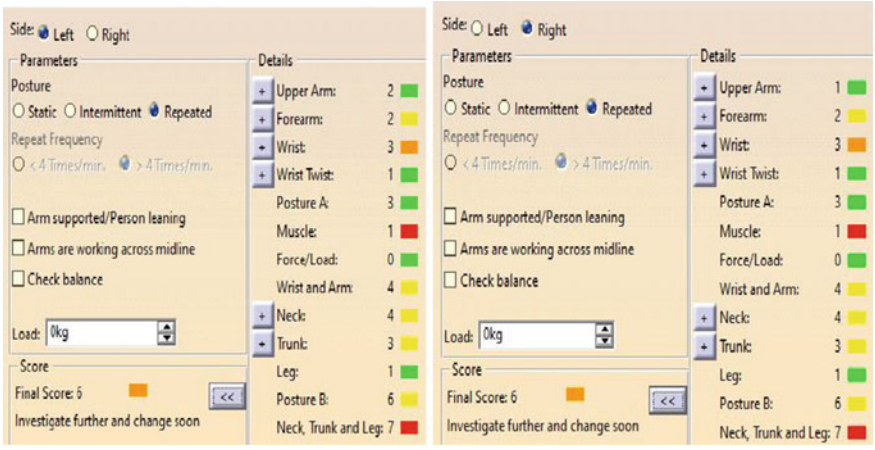

Fig. 3 RULA score of left and right side

Reach analysis done by examining the envelope tool as provided in Human Activity Analysis workbench in CATIA. In current posture it is 65 cm as against the recommended range of 45–60 cm. This calls for a workstation redesign to reduce the reach distance. Vision Analysis in the DHM found the visual cone angle to be 6°, focus distance to be 12.2 cm and binocular view display scale—1:2. As it deviated from the recommended value of 25° view cone and 30 cm focus distance, a workstation redesign for visual cone is required. Thigh clearance analysis found the clearance to be unsatisfactory. Overall, an ergonomic redesign of the workstation is required.

5 Conclusion

Ergonomic analyses of the workstations indicate the risk of MSD development among the office workers. Overall ROSA score is high which indicates that further research and modification of workplace is necessary. Section score for Chair is higher comparing to other section which implies that the chair should be modified. Assessment of the environmental conditions shows that the lighting, temperature and ventilation condition should be improved. RULA analysis of existing workstation using digital human modeling confirmed the workstation issues, and the need for workstation redesign. In addition, there is scope for improvement in the office layout attributes such 'Workplace orientation', 'Availability of free space', 'Access to equipments' and 'Workplace separations' in the firm. Further work includes ergonomic redesign of workstation and workplace for the consulting firm.

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Personalizing Helmet Designing for Bengalee Adolescents Receiving Training in Hockey: An Anthropometric Approach

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Abstract Goalkeeping is specialized position in hockey especially from the standpoint of injury risks involved because of the nature of the game including the mass of the ball used. Generally, the helmets available are designed taking into consideration, the adult body especially the cephalic dimensions. But receiving training for developing into a well-trained player involves initiating the training process much before attaining the adulthood in tune with the philosophy catch them young. In this backdrop an attempt is being made to develop a design of a helmet meant for the Bengalee adolescents, who should ideally receive more protection from injuries for lack of skill and experience to protect them. The relevant anthropometric parameters especially the cephalic dimensions like head breadth and length were measured using spreading caliper from 48 consenting individuals. A personalized design of the helmet meant for the goalkeeper from the Bengalee adolescent population was proposed subsequent to mathematical modeling.

Keywords Risk management · Goalkeeping · PPE · Mathematical modeling · Body physique · Customized design

1 Introduction

Hockey is an ancient game considered as the national game of India which is also known as "stick and ball" games. Hockey was introduced in India during the period

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of British rule and at present five continental and one hundred and thirty two national associations are the members of the International Hockey Federation [1, 2]. Sporting activities like hockey hold a risk of occurring facial injury including traumatic impacts from fellow competitors, projectiles, and close body contact with posts or the ground injury as high-speed stick movement requiring to hit a puck or a ball. Moreover it hampers sport performance, team performance and compromises success over the sporting season. Studies have indicated that wearing ill-fitted helmet increases the likelihood of head injury compared to properly filled helmet [3]. It has been reported from another study carried out on Asian people, indicated a poor Helmet Fit Index (HFI) score, which provides a fit 'score' for the combination of one specific helmet model and a human head, of helmets designed for human heads of varied shapes leading to discomfort [4] during match. On the other hand, the shape of human head is influenced by different factors including gender, and ethnic background [5]. Earlier studies reported that anthropometric parameters like stature, standing and sitting heights bearing significant correlation with cephalic dimensions like head length, head breadth and cephalic index may be considered to facilitate proper stability and fit of helmets [6]. Studies have indicated that the existing range of sizes of commercially available helmets might not fit the varied range of human head dimensions and shapes. In this backdrop, a study has been conducted on Bengalee adolescents receiving training in hockey to design 'customized' helmets based on anthropometric data using prediction modelling.

2 Methodology

The data were collected from 48 adult males (age range 13–19 years), permanently inhabiting at the Nadia District, in West Bengal and these data represented as data of Group 1. After getting the initial consent from the study participants, study requirements explaining elaborately. Individuals who were on medication or had some musculoskeletal problem (self reported) excluded from the study purview. Age (years) was recorded in pre designed schedule. Stature (cm) was measured using anthropometric measurement set and the cephalic dimensions—head length (HL) and head breadth (HB) in cm, were measured using spreading calliper [7, 8]. HB was measured as the maximum biparietal diameter, (the distance between the most lateral points of parietal bones (euryon)) and HL was measured as the straight distance from the glabella (the prominence on the forehead between the eyebrows, just above the nose) to the opisthocranion (the farthest occipital point) [8]. Cephalic Index (CI) was calculated from the ratio of HB to HL [9, 10]. The measurements were also obtained from 53 adolescent Bengalee males of similar age range and socio economic stratum and these data represented as data of Group 2. Obtained data were statistically analyzed. Arithmetic mean (AM), standard deviation was calculated. P value less than 0.05 was considered as statistically significant.

3 Result

Table 1 represents Group 1 study participants' anthropometric parameters along with coefficient of correlation. It has been found that a significant ($P < 0.05$) positive correlation exists between stature and HB in Group 1 study participants and therefore, regression equation was developed; HB, one of the important parameters for helmet designing, has been computed using stature (X), an easily measurable yet important anthropometric parameter, as the predictor.

The regression equation for HB (Y) estimation using stature (X) as the predictor is as follows:

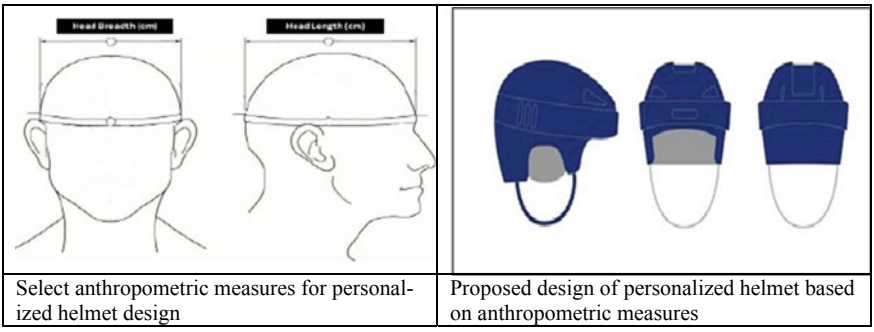
$$\hat{Y} = 10.847 + 0.022 * X$$

If this model is translated, at the point of purchase, guardians of the adolescent trainee hockey players can be counseled regarding selection of a proper helmet for the player by the shopkeeper just by knowing standing height, an easily measurable anthropometric parameter which will improve the performance at the time of practice as well as during actual match (Fig. 1).

Table 1 Anthropometric parameters of group 1 study along with coefficient of correlation

Variables	Group 1 individuals
Sample size	48
Age (years)	16.4 ± 2.14
Stature X (cm)	163.9 ± 8.47
HL in cm	17.5 ± 0.72
HB(Y) in cm	14.5 ± 0.59
CI	0.82 = 0.032
Rxy	0.34*

AM ± SD, *P < 0.05, ^ns



Select anthropometric measures for personalized helmet design

Proposed design of personalized helmet based on anthropometric measures

Fig. 1 Select anthropometric measures for personalized helmet design and proposed design of helmet based on the anthropometric measures

4 Discussion

In the present study, the BMI of the participants (17.9 ± 2.09) lies within the 'normal range" [11]. The result is in consonance of our previous study conducted on sub division trainee adult and adolescent football players [12–17] and also in Bengalee females receiving training in Indian classical dances [18–22].

Despite helmet being essential protective equipment for goalkeepers, usually players refuse to wear it during match. It has been reported in earlier studies that improper fit and discomfort are the two major things which basically play an important role in not to wear helmet during game situation [23]. According to the National Collegiate Athletic Association of United States all field players are required to wear mouth guards at all times during a match. Therefore to improve compliance, it may be required to check athletes before going to the ground. On the other hand, implementation of penalties for not wearing the proper equipment could be one of the protective measures for not getting injured. It has already been reported, that the type of human head shape is influenced by ethnicity, genetic interaction, nutritional status and gender, it may be the reason that why vast anthropometric variations exist among various ethnic populations [9]. Studies carried out on size, fit and stability of a helmet have shown that the existing range of sizes of the commercial helmets may not be appropriate due to wide variations in cephalic dimensions among humans of different ethnicity [24–26], hence the result is discomfort which may be one of the main reasons of avoiding using helmets during practice and even in the actual game. To decrease this problem, incorporating techniques to design 'customized' helmets by considering the influence of gender, ethnicity on human head shape may be adopted [26]. There are various anthropometric parameters and indices having close relationship with helmet design, in the present study stature has been identified as the predictor. Stature bears a correlation between different anthropometric parameters; therefore estimation of cephalic dimensions from stature of an individual may prove to be promising in reducing the discomfort rate of the wearer [27], by proper fitting to the wearer. In the present study, the study participants are Bengalee adolescent who are undergoing training in hockey. It has been found that, in case of Group 1 participants' stature was found to be significantly correlated ($P < 0.05$) with HB. Earlier studies carried out among different ethnic groups and populations [28, 29] have found a similar trend of result which reports stature was found to be significantly correlated ($P < 0.05$) with HL. The finding of the present study is in tune with our previous work carried out on Two-Wheeler Users [30]. In order to improve the existing range of sizes of the commercially available helmets designing 'customized' helmets like that of tailored-fit dresses, on the basis of cephalic dimensions of an individual predicted from his/her stature, may prove to be effective. Since it has already been mentioned that proper fit and stability of helmet is not just important for maintaining comfort level of the wearer but also from the perspectives of a helmet's protective ability, improving helmet design in terms of size and proper fit is therefore, essential and in turn may encourage player to wear helmets at all time. Small sample size for being a sort of a pilot study, present work has immense scope

to improve for ensuring the safety of the players. Despite the limitation, the study has immense scope. If this model is translated, at the point of purchase, guardians of the adolescent trainee hockey players can be counseled regarding selection of a proper helmet for the player by the shopkeeper just by knowing standing height, an easily measurable anthropometric parameter which will improve the performance at the time of practice as well as during actual match.

5 Conclusion

It may be concluded that in case of adolescent Male Hockey players (i.e. study participants belonged to Group 1) inhabiting at Nadia District, Hooghly West Bengal, stature bears a significant positive correlation with HB and therefore, it may be applied to estimate the HB by using prediction equation model. It may also be concluded that to improve comfort and fit of a helmet, modification of the existing range of sizes of the commercially available helmets by including the influence of gender, ethnicity and like on cephalic dimensions may be effective. Therefore, to encourage helmet use among Hockey players specifically goalkeepers in order to reduce the number of injury at the time of game situation, employing techniques to design 'customized' helmets on the basis of cephalic and other anthropometric dimensions may prove to be fruitful.

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A User-Centered Comparison of Novelty and Typicality in Product Designs Using Pictorial and Augmented Reality (AR) Representations

K. Rambardhan and Dhananjay Singh Bisht

Abstract Consumers prefer visually appealing products. The nature/mode of visual representation of a product has direct consequences for design and usability of screen-based user interfaces and work systems. Today, augmented reality (AR) based technologies using different devices, are being popularly considered for product representation. In this paper, a user perception based comparison between AR-based and pictorial digital image based product representation has been made using subjective inputs from Design students. Preliminary user-research was conducted to determine the most relevant design descriptors of product appearance for the design properties of novelty and typicality. The comparison between the two representation styles was performed on the basis of the following design descriptors found in the survey results—*creative, modern, unique, stylish* and *futuristic* (novelty) and *basic, common, old, classic* and *simple* (typicality). It was found that AR representations received favorable ratings to an extent of 6–8% higher than that of pictorial representations.

Keywords Product display · Augmented reality · Novelty · Typicality

1 Introduction

Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information [1]. Computer-aided design (CAD) is perhaps the most powerful visualization tool for designers. But, traditional CAD representations may not be sufficient for information rich and fulfilling interactions with the product. It is specifically for such situations that technologies like virtual reality (VR) and augmented reality (AR) are being used popularly today for three-dimensional (3D) representational purposes. Especially, in the product design process, AR can be used for collaboration among different stakeholders for purposes such as product representation, design evaluation, etc. [2]. During product evaluation, the use of AR makes it easier to visualise the product and reduce the evaluation time [3]. AR-based digital

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experiences can improve product exploration, visualization and modification [4]. Some studies suggest that AR users have increased up to 800 million worldwide in the year 2021 [5]. The same study also forecasts that the number of AR users will reach 1.73 billion by the year 2024.

In product design, various design elements could be analysed to evaluate different product characteristics such as aesthetics, functionality, etc. [6]. In the past, different research works have been conducted to explore the various design properties and their effects on product experiences [7]. A particularly interesting perspective to product experience is offered by the preference-for-prototype theory which suggests that a product choice is mainly influenced by its typicality and ability for categorization [2]. At the same time, it has also been observed that consumers in their design choices also prefer to use a concern for novelty which as a concept is semantically opposite to the ideas of similarity or familiarity [7]. Therefore, there exists enormous possibility of exploring the effects of design parameters like novelty and typicality in design choices/preferences.

It has also been observed that small variations in design properties can significantly impact product assessment by consumers [8]. These design properties could even interact significantly with one another. There is a need therefore to investigate design properties like novelty and typicality in different controlled experiment settings such as those facilitated by variable visual stimulus, user background, design expertise, etc. [9]. The aim of this research to conduct a survey-based comparative evaluation based on the design properties of novelty and typicality for products represented in—(1) regular digital pictorial format, and (2) augmented reality (AR) format based on the subjective inputs from Design students.

2 Methodology

Three user surveys were conducted during this research work. The following objectives were achieved using these surveys—(i) descriptors related to design parameters were collected; (ii) consumer product categories perceived to be more novel and typical were determined, and; (iii) the difference between pictorial and AR representations were examined. For these three surveys, Design students who had proven merit in Design skills and knowledge were approached to participate in the study. Many of them volunteered. Convenience sampling was employed based on the availability and acceptance of student participants for the test and therefore, the numbers of participants were different in the three surveys. A general expectation was that responses from each of these samples would approximate the general view of the Design student population at the Institute. Design students have a heightened sense of visual acumen and were formally knowledgeable of many Design principles. Prior to each survey, a brief description about the experiment was provided and any doubts were clarified. The test conditions were standardized and the participants were given complete freedom to—not take the survey at all, or to quit at any point in time during the survey.

2.1 Survey-1: Collection of Descriptors

The objective of the first survey was to collect the descriptors related to design properties of novelty & typicality with the help of 25 different products. A total of 40 undergraduate and postgraduate students studying Design (age range of 20–30 years) volunteered to participate in the survey. As stimulus, digital images of 25 distinct daily use products namely—hanging chair, wooden chair, chess board, cap, spiral table lamp, mouse, plastic box, table, candle, Alexa speaker, alarm watch, vase, bottle, shoe, coffee table, telephone, computer desk, suitcase, cup, shelf, table lamp, speaker, perfume bottle, plate and modern chair were used. The participants were required to categorise each of these products as either novel or typical with reasons provided using adjective descriptors for each. Instead of attributing product names, numbers were assigned to each product and all visible brand marks were obscured in order to eliminate any brand biases. The participants were also asked to indicate any other product categories which they perceived as examples of very novel or typical products.

2.2 Survey-2: Novelty and Typicality Ratings

12 Product categories were identified as stimulus for this survey with the help of inputs from Survey-1. These were—*table, chair, stool, bottle, cup, handle, table lamp, fan, work desk, shoe, speakers* and *watch.* 88 UG and PG Design students (17–30 years) volunteered for this survey. The objective of this survey was to determine those product categories where the users perceived that there exists the greatest extent of novelty to typicality design variation in the available models in the Indian market. They expressed their opinions on the list of 12 product categories using a 5-point Likert scale where the rating "1 = least extent" to "5 = highest extent" of novelty-typicality variation [10]. No images were used in this survey as stimulus. Participants were also required to indicate a design of the most typical and the most novel model for each product category.

2.3 Survey-3: AR vs. Pictorial Representation

A total of 180 UG and PG Design students (17–30 years) volunteered for this survey. The first part of this survey involved collecting information regarding their knowledge of various visual representation technologies namely virtual reality (VR), augmented reality (AR), mixed reality (MR) and extended reality (XR) [11]. A questionnaire was later administered to determine the extent of novelty and typicality experienced by the participants when viewing the same visual stimulus through firstly pictorial representation and then AR representation. Also, the stimulus to be used for this survey was

six different models of the same product category identified from the Survey-2. The evaluation of novelty and typicality was made using 5 most recommended descriptors for each of these properties from Survey-1. For stimulus, 3 novel and 3 typical models were used. These 6 models were the most recommended by participants and all belonged to the product category with the most novelty-typicality variation in Indian market designs (Survey-2). The participants had to rate the 3 most novel products using the 5 novelty verbal descriptors shortlisted earlier from the Survey-1 results. Similarly, they rated the 3 most typical products on the 5 most typical verbal descriptors from the Survey-1. These models were shown to participants in a random order to eliminate the sequence bias. The participants had to rate these products on the descriptors using 5-point Likert scale where the rating "1 = least extent" and "5 = highest extent" of agreement to a descriptor. One set of readings were taken each for digital pictures and AR representations of each stimulus. A paired sample t-test was used for comparing the data for pictorial and augmented reality view [12]. The analysis was conducted using IBM SPSS Statistics 24 [13]. The null hypothesis was that the ratings of descriptors for both pictorial and augmented reality view are the same. Significant difference was measured for 95% confidence interval ($p < 0.05$).

3 Results

3.1 Collection of Descriptors

Analysis of Survey-1data led to identifying a total of 58 verbal descriptors for novelty and 50 descriptors for typicality. From these results, the top 5 (most reported) verbal descriptors each for novelty and typicality were documented for further use (Table 1).

Table 1 Top 5 most cited adjective descriptors for novelty and typicality

Top 5 most cited adjective descriptors for novelty	Top 5 most cited adjective descriptors for typicality
Creative	Basic
Modern	Common
Unique	Old
Stylish	Classic
Futuristic	Simple

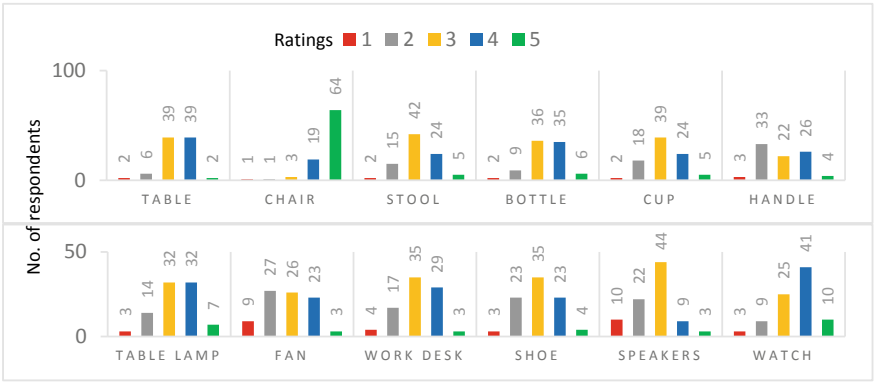

Fig. 1 Product category ratings for greatest novelty-typicality variation

3.2 *Extent of Novelty and Typicality*

The analysis of Survey-2 data determined the products which were rated as the most novel and the most typical. From the given 12 product categories, chair was indicated by a large number of users as the product category where the most novelty-typical variable designs were available in the market. Chair was therefore considered as the stimulus category for the Survey-3. Figure 1 shows the extent of novelty-typicality variations in different product categories as perceived by the participants where the rating "1 = least extent" and "5 = highest extent" of variation.

3.3 *Comparison of AR with Pictorial Representation*

Figure 2a shows the number of participants known to various immersive technologies. It was found that 80% of the participants knew about VR, 58% knew about AR, 14% knew about MR and only 9% knew about XR. Figure 2b represents the use of AR by the participants. It can be seen that 68–76% of participants had used AR technology prior to the survey.

The extents of agreement to the different verbal descriptors of novelty and typicality were found in this survey and the differences in ratings were compared—for the pictorial view against AR view for six chair models (typical: Models 1–3; novel: Models 4–6) (Fig. 3).

From Table 2, it can be seen that there existed statistically significant differences (at $p < 0.05$) among the pictorial and AR representation user ratings in the typicality spectrum for the 5 verbal descriptors namely—*basic, common, old*, *classic* and *simple* for all the models except Model-2 and Model-3. In all cases, AR representation was rated better than the pictorial representations. For Model-2 and Model-3, statistically

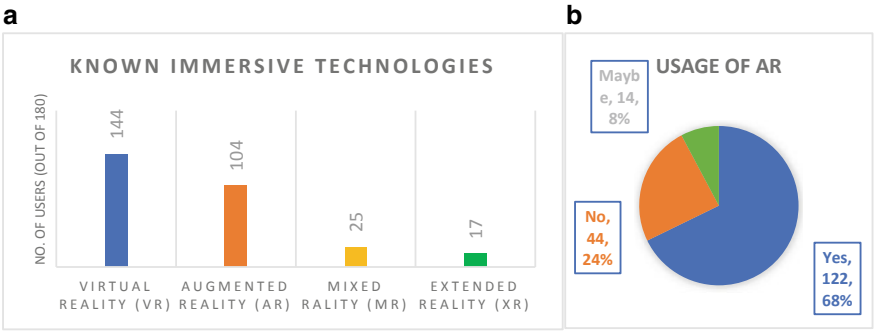

Fig. 2 **a** Knowledge of participants about immersive technologies. **b** Usage of AR among participants

Fig. 3 Three typical and three novel chair designs used as stimulus for the survey-3

significant differences in the ratings were not observed for the ratings of the descriptor *simple.*

Also, through product representation analysis on the novelty spectrum, in Table 3 it can be seen that there existed statistically significant differences (at $p < 0.05$) among the pictorial and AR representation user ratings for the 5 novelty verbal descriptors namely—*creative, modern, unique, stylish* and *futuristic* for all the 3 models except for Model-5. For Model-4 and Model-5, statistically significant differences in the ratings between pictorial and AR representations were not observed for the ratings of the descriptor titled *stylish.*

Table 2 Paired sample t-test data for typical model-1 to model-3 between AR and pictorial representations representation representations

Model No.	Verbal descriptor	t-value (df = 179), AR vs. pictorial representation	Sig. (*p*) (2-tailed)
1	Basic	3.373	0.001
	Common	3.655	0.002
	Old	3.528	0.026
	Classic	2.950	0.001
	Simple	1.345	0.004
2	Basic	3.373	0.001
	Common	3.655	<0.001
	Old	3.528	0.001
	Classic	2.950	0.004
	Simple	1.345	0.180
3	Basic	3.124	0.002
	Common	2.825	0.005
	Old	2.025	0.044
	Classic	4.365	<0.001
	Simple	1.135	0.258

Table 3 Paired sample t-test data for typical model-4 to model-6 between AR and pictorial representations representation representations

Model No.	Verbal descriptor	t-value (df = 179), AR vs. pictorial representation	Sig. (*p*) (2-tailed)
4	Creative	3.662	<0.001
	Modern	5.290	<0.001
	Unique	3.736	<0.001
	Stylish	1.016	0.311
	Futuristic	4.544	<0.001
5	Creative	3.968	<0.001
	Modern	3.688	<0.001
	Unique	2.996	0.003
	Stylish	1.251	0.212
	Futuristic	4.615	<0.001
6	Creative	4.634	<0.001
	Modern	3.139	0.002
	Unique	3.921	<0.001
	Stylish	2.221	0.028
	Futuristic	4.215	<0.001

From the results in Tables 2 and 3, it can be seen that the mean ratings of the novelty or typicality descriptors increased when represented in AR format by almost 7% for Model-1 and Model-4, by almost 6% for Model-2, Model-3 and Model-5 and by almost 8% for Model-6 as compared to pictorial representation.

4 Discussion

There are a few valuable decisions and results which could be discussed in some detail. First, in the three surveys, the researchers relied on volunteering from the students. Therefore, convenience sampling was employed based on the availability and acceptance of student participants for the test and therefore, the numbers of participants were different in the surveys. A general assumption was that responses from each of these samples would approximate the generic view of the Design student population at the Institute.

It is also worth noting that Fig. 1 shows the results of user ratings clearly dominated by perceptions of typicality rather than novelty. This was expected, as the 12 categories of stimuli were all everyday products. Also, Table 2 indicates that the respondents gave similar ratings to the visual descriptor *simple* for Model-2 and Model-3. This might be the case because these models have plain uncomplicated forms that can be visualized through AR without any significant benefits over regular pictorial representation of providing additional detailed visual information. Similarly, in Table 3 for the visual descriptor *stylish*, the ratings given by respondents were similar for the AR and pictorial representations possibly because these products seem to be instantly very aesthetic and pleasing, and therefore there is little scope for further discriminating between the perceptual effects of these designs.

Also, according to the paired *t*-test results, AR view was found to be significantly ($p < 0.05$) more effective in novelty-typicality experiences than the pictorial. The mean AR representation ratings were significantly higher and different than the ratings for pictorial representation. Therefore, it could be inferred that adoption of AR in visual representation of products as compared to the traditional pictorial means, could heighten the perceptions of novelty and typicality while experiencing products.

5 Conclusion

Augmented reality (AR) is increasingly being viewed as a prominent service business tool for assisting brands in providing appealing online visual experiences. In the past, customers have found AR experiences as highly informative, exciting, and interactive.

Results from this study suggest that digital product representations can achieve better experiences on the novelty-typicality spectrum using AR representations as compared to the traditional pictorial means. The use of AR representations achieved

higher novelty-typicality ratings to a range of 6–8% than that of pictorial representations. In AR, the possibility of offering a 360° view lends richer information to the viewers in terms of actual size, texture and the environment details where the product is situated. Also, as nearly 70% of the respondents had an exposure to AR technology, it appears to be a promising option for visual e-commerce sites and applications to offer AR representation options for the products on sale. These results support a case for offering AR product representations through digital screens and related work systems.

This study was limited to understanding the generic view of a specific population sample with no specific attempt at understanding perceptual differences among the participants. There is a huge scope for conducting similar analyses on different populations and by considering a greater variety of products to gain a more holistic understanding of the perceptions towards AR representations by a wide range of users. Intra- and inter-group perceptual differences based on demographic parameters such as age, gender, specialization, etc. could also be considered while making inferences in future research. Results from any similar studies can be used by product manufacturers to improve the specific visualization experiences on different digital platforms.

Declaration This paper has been developed from the major-thesis work completed by the first-author at Industrial Design department, National Institute of Technology, Rourkela submitted during May, 2021.

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Kinetic Reciprocation in Landscape Architecture: An Exploration of Visitation Patterns in Dutch Urban Parks

Barsha Amarendra

Abstract There has been a long-standing tradition of scholarly thoughts that visual perception is intricately linked to the possibility that the landscape affords for movement. The existence of a path facilitates our ability to see and experiencing the landscape. It's design articulation determines how we move through, and participate in it. This paper provides an understanding of the different movement patterns as a consequence of path design through the review of existing writings on the interdependence between the visual reception of gardens and kinaesthesia, along with an exploration of the routing design in two prominent Dutch Urban Parks. John D. Hunt's seminal work on movement patterns forms the basis for the paper's exploration into Amsterdam's Vondelpark and Utrecht's Máximapark, which have been chosen as representative cases for Dutch urban parks. In doing so, the paper highlights the possibility of different movement patterns co-existing together and ways of designing for that. Additionally, the paper validates much of the existing theory on movement patterns and provides substantial points of observations to enrich it further.

Keywords Kinaesthetic experiences · Poetics of movement · Dutch urban parks · Routing design · Landscape architecture

1 Introduction

The European Landscape Convention (ELC) defines landscape as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" [1]. Although 'perceived by people' refers to a holistic experience with all senses, very often it is reduced to the visual aspects [2]. According to Harris and Fairchild Ruggles, this peculiarity of limiting the understanding of perceived by people to visual aspects is because "For most human beings, the primary way of knowing the material world is through vision; the simple act of

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opening one's eyes and looking at an object, a scene, a horizon" [3]. However, there has been a long-standing tradition of scholarly thoughts that landscape perception is a combination of all our different senses, rather than being a purely visual aspect. In particular, it is well acknowledged by the academic fraternity that visual perception is intricately linked to the ability and the possibility that the landscape affords for movement. From Joseph Addison to William Gilpin, from Alexander Pope to Claude-Henri Watelet, the walk has long been conceived as an act of perceptual participation in the landscape—an involvement in both forming and transforming its surroundings [4]. Crucial to this experience of the landscape through movement, is the path. As C.C.L Hirschfeld stated, the path is an aesthetic orchestration: a device for seeing and experiencing the landscape [4]. In absence of a well-designed routing, even the most meticulously designed landscape can fail since people will not be motivated to move through its space and thereby form connections with it. Paths are, thereby, 'silent guides of the stroller' and facilitate the primordial act of walking as an aesthetic and social practice [5].

Hence, the understanding of routes, the visitation patterns it can orchestrate, and the consequent visitation experiences that are created, are very much a valid theme in contemporary theoretical studies on designing spaces for an enriched, experiential engagement. An understanding of the experiences afforded by the path design can help landscape architects to get a grip on space as perceived from eye-level, kinaesthetic aspects, way-finding, and the phenomenology of landscape to become tools for landscape design [5].

This paper provides an understanding of the different movement patterns as a consequence of path design through a review of the existing writings on the interdependence between the visual reception of gardens and kinaesthesia and an exploration of the routing design and movement patterns in two prominent Dutch Urban Parks. In doing so, the paper would practically unravel how path design and materialisation creates varied movement patterns and thereby, varied experiences in space.

2 Setting the Scene

2.1 Movement Patterns in a Landscape

One of the first scholarly commentary on the linkage between movement and sight in a garden defining visitor experiences, came from Sir Henry Wotton in the Elements of Architecture, 1624. John Dixon Hunt's seminal treatise 'The Lordship of the Feet' was a follow up on Wotton's assumptions that gardens are designed for walking, and thereby proposing a classification of movement patterns in gardens. These movement patterns determine the spatial and visual experience within a landscape composition, along with the relationship between the different elements of the composition. Hunt's classification forms the basis for this paper's exploration.

The first movement pattern is that of the procession. Hunt states that, "The procession is a ritual movement that follows both a preordained path and purpose…" and further highlights the religious or allegorical nature of the movement, that sometimes refers to a context beyond the site of ritual movement. Thus, a ritual movement can be understood as a prescribed path in a garden, dotted with forms and elements that construct a narrative for the visitor to interpret [6]. Madame de Scudery and Louis XVI's narratives for the Garden of Versailles present some of the most well documented narratives of prescribed movement through a garden.

The second movement pattern is that of the stroll, which is characteristic of the picturesque gardens. Hunt ascertains that gardens for stroll "have been contrived to give the stroller incentives for moving forward. These incentives are either a clearly designated path or a series of events and incidents along that path, usually both." The English Heritage estate of Stourhead presents a distinguished example of a stroll garden, due to the visual cues that it frames for the visitors to be tempted to walk on. The spatial qualities of the stroll, can also be found in the design of routings in Nature reserves and museums, wherein, the visitor walks on due to the expectations of discovering new sights.

The third and the last movement pattern is that of the ramble, which Hunt ascribes as the easiest. Ramble is understood to be a movement without any external prompt, or any definite and pre-ordained paths and largely based on own self will to explore [6]. Ramble can be of three typologies; multiple defined pathways to choose from as in West London's Chiswick Gardens, multiple meandering pathways through a natural setting as in Manhattan's Central Park or vast open lawns as in Brooklyn's Prospect Park. But what ties them together, is the choice given to the visitor to make his own route of exploration and the uncertainty of what he will discover.

The study of these movement patterns also necessitate an understanding of the specific landscape themes that each movement describes. The site for procession is designed as a metaphorical representations of elements and allegorical spaces, tied together by a narrative. The setting for a stroll is that of a pictorial landscape to be explored by tempting the visitor through visual incentives and opportunities for rest and contemplation. For the ramble, Hunt states that "The ramble requires or seeks a natural or naturalistic topography." While landscape designers like Olmstead refer to their work as natural, as Spirn states, to describe one sort of garden as natural implies that there are unnatural gardens, which are somehow different (and presumably wrong) [7]. As products of culture, ideas of nature vary from people-to-people, place-to-place, period-to-period [8]. In fact, the understanding of what is natural varies even amongst contemporaries. As such, central to the understanding of ramble is not that it seeks a natural setting; the notion of which corresponds to our individual notions of what is natural; but that it provides for a disconnected wandering. Disconnected wandering implies that the visitor is disconnected from others and is rather self-involved in wandering through the landscape, the way he wishes. Hunt himself establishes this character of the ramble by stating that "a ramble is solitary" [6].

2.2 Preference Accorded to Movement Patterns

As touched upon during the elaboration of the ritual, historical narratives for movement through a garden emphasised undertaking a specific movement pattern, thereby ritualising it. Present-day guidebooks and visitor's maps play the same role of prescribing the existence of one route par excellence through a garden. This prescribed movement pattern, oftentimes, is not intrinsic to the garden's design, but rather, an outcome of accommodating an increasing number of visitors to appreciate the most significant spaces within a garden. In a picturesque garden designed for a stroll, this prescription of movement route leads to ritualising the stroll route, thereby modifying the subsequent visitation patterns through it. Eminent English stroll gardens such as the Stourhead, Rousham and the Studley Royal garden, to name a few, have had their visitation patterns ritualised by narratives framed by the visitor's maps and guidebooks.

This discussion transpires the question whether gardens can cater to different movement patterns at the same time, or are designed to accommodate only a certain movement pattern which can be altered by employing design intervention or attaching narratives to the routing sequence. In the Lordship of the Feet, Hunt illustrates through his case studies of Pope's garden at Twickenham, the gardens at Chiswich and Rousham, that there are gardens that have catered to more than one movement pattern. However, the understanding of how landscapes typologies of today accommodate different movement patterns and their interaction with one another is absent.

2.3 Incorporating Stillness in Movement Patterns

The primacy that Hunt accords to walking as a place-making practice conforms to the conventional scholarly discourse of recognising movement as the determining factor in establishment of place [9] and disregards the role that stillness has in a landscape's kinaesthetic reception. This stands in contrast to the Oriental East's conception that experience of motion and stillness are mutually embedded cardinals for landscape reception. Moments of stillness create an awareness of the motion described through a landscape along with catalysing a fusion of self and object [10]. Additionally, incorporating moments of stillness enables a wider demographic user group such as the elderly and parents with young children to relish in totality the landscape and its elements that the route intends to unravel. Stillness, is thereby, intrinsic to a landscape's kinaesthetic reception. As such, it would be a valuable addition to explore how the design of resting spaces enhance the experience of the movement patterns described. For this endeavour, Hunt's elaborate characterisation of each movement pattern serves as a rich, starting ground for extraction of clues.

3 On-Site Materiality of Movement Patterns

Based on the theoretical knowledge of the preceding section, two urban parks would be explored for their routing design and the consequent movement patterns through the designed landscape. This choice is based upon two notions. Firstly, urban parks are large enough to have multiple entry points, thereby, forestalling attempts at creating a route par excellence with a designated start and endpoint. Secondly, unlike the estate landscapes such as the Stourhead or Rousham, urban parks are designed to become a subtle, yet profound part of the public daily life, thereby, curbing the necessity of creating and promoting guidebook routings for experiencing the space. The next step of choosing specific urban parks for studying was determined by screening criteria that they be situated in different urban centres and belong to different time periods of realisation, to avoid generalisation of findings to an entire country, which exhibits a rich legacy of uniquely designed urban parks. As such, Amsterdam's Vondelpark, Rotterdam's Kralingse Bos, Utrecht's Máximapark, Maastricht's Stadspark and Groningen's Noorderplantsoen were narrowed down upon, for the study.

Each of these parks were analysed through an extensive literature review of their history and design ideation, along with analysing the park's design drawings, in order to establish a sound understanding of the routing patterns. The next part of the study was to practically analyse the movement patterns as a result of the design layout, by means of walking through each of the parks. The paper presents the research findings from Amsterdam's Vondelpark and Utrecht's Máximapark for being representative of the movement patterns found in the larger set, along with showcasing clear distinction in design articulation to facilitate a comparison between kinaesthetic experiences.

3.1 Vondelpark

Upon its realisation in 1896, Vondelpark became Amsterdam's first urban park, followed by a status change in 1996, when it was designated as a National Landmark. Attracting 10 million visitors every year, the Vondelpark has earned the reputation of being the country's most popular urban park.

As illustrated by Fig. 1, the visitor map at Vondelpark categorises the routing options through the park into asphalt paths and walking paths. The asphalt routes which are designated for cyclists describe two smaller loops that connect to form a larger peripheral network to travel across the park. The walking paths are laid in an organic pattern and take the visitors to experience the elements within the park.

The 7 m wide asphalt paths are designed as avenues for cycling with walking paths flanking them on both sides. For a walker, the asphalt paths embody the experience of a stroll due to the multiple points where the walking paths diverge from alongside it to explore the sights within the park as seen in Fig. 2. For a cyclist, the limited opportunities for choosing an alternate route, coupled with the lack of visual cues to incentivise going onward curates a ritualistic experience.

Fig. 1 Map of the Vondelpark showing the various categorisation of paths within the park. *Source* maps-amsterdam-nl.com/maps-amsterdam-attractions/vondelpark-amsterdam-map

Fig. 2 Unpaved routes for strolling diverge from the asphalt routes to take visitors to the elements within the garden. *Source* Author

Fig. 3 View of the pavilion and the bridge to it from the stroll path act as incentives to carry on the existing path. *Source* Author

Designed in the picturesque, English landscape style with the intention of being a green space for strolling, the walking paths through Vondelpark exude the character of a stroll. The rugged, dirt paths are designed to meander through meadows and bring people closer to the park's water features. As illustrated by Fig. 3, landscape architectonic elements such as bridges, and art pieces, along with architectural buildings such as cafes and pavilions, are designed to become visual cues.

Fig. 4 Stylised benches along paths draw visitor's attention. *Source* Author

The opportunity for resting is designed as a visual cue in itself by drawing people to look closely at its distinct styling as in Fig. 4. On the walking paths alongside the asphalt paths, benches are placed every 600 and direct the visitor's contemplation upon the sights within the park. The seating in the park's core are placed at points that allow a close appreciation of the landscape architectonic elements of the route.

3.2 Máximapark

Spreading across 300 ha on the western edge of the city of Utrecht, the Máxima-park is Netherland's largest urban park. Every since its inauguration in the 2013, it has become a celebrated forest park, that acts as a pivot for social interaction and recreational opportunities for the urban districts around it.

The sheer size of the park necessitates signage maps in two different scales for visitor's alignment and information. Figure 5 shows the signage map at the entrance points to the park, highlighting the Het Lint; a wide, peripheral ring for cycling, skating and walking; and discarding the representation of the park's interior routes. Upon entering the Binnenhof; the heart of Máximapark; one encounters a detailed route map consisting of the intimate routes that cater to either both walkers and cyclists or only walkers, as illustrated by Fig. 6.

The 7 m wide Het Lint is adorned with daisy motifs on its asphalt and the concrete curb-stones edging it, throughout its length of 8kms through meadows and along forested edges as illustrated by Fig. 7. The figure also highlights the intimate scale that these motifs add to the Het Lint, whose substantial width and length along with the vast landscape it transverses through outsizes the scale of the user. Its size, materiality and its layout that facilitates directing people towards the park's main sections, ensues the Het Lint to promote a ritualistic movement pattern.

The second hierarchy of routing can be attributed as the stroll, which have been designed for the Binnenhof. The experience of strolling has been materialised by employing two distinct design strategies as seen in Fig. 8. The first strategy is that of designing path intersections such that the visitor is allowed a path choice, based upon which direction visually interests him. The second strategy is that of using landscape

Fig. 5 Visitors map highlighting the peripheral path of Het Lint, along with existing car roads and train line. *Source* Author

architectonic elements of bridges and park pergolas, and architectural buildings of cafes to entice the visitor to choose a particular direction.

The third hierarchy of routes in the park are that of ramble. These paths are devoid of any visual cues to carry on the path; their choice, relying upon the curiosity of the visitor, or for simply enjoying the pleasures of walking on. Although these paths are also laid in asphalt, the absence of visual cues make them distinct from those exuding a stroll.

The seating design in the park has been conceptualised to be same along the Het Lint and the stroll paths, with the ramble paths not having any. The seating along the Het Lint is placed every 800 m and serve the purpose of being a pitstop, which on which few occasions engage the visitor's gaze upon the Park Pergola, but for most of its length, shows disengagement with its setting as illustrated by Fig. 9. In contrast, the seating along the stroll routes create a sensory engagement with the landscape setting around it, as seen in Fig. 10. These seating units do not subscribe to a fixed distance between their placement, but are rather subject to opportunities of engagement with visual cues along the path.

Fig. 6 Visitors map highlighting the more intimate pathways designed in the park's Binnenhof. *Source* Author

Fig. 7 Daisy motifs on the asphalt and daisy engravings on the curb stones flanking the path provide a human scale to the Het Lint and its landscape setting. *Source* Marnix Schmidt

3.3 Comparison of Kinaesthetic Experiences

The possibility of incorporating distinct kinaesthetic experiences into a park's fabric through routing design can be further aided through a comparative analysis of the two parks. Since this comparison is based on the experiences that transpired during the method of walking through the two parks, the movement pattern of ritual will not

Fig. 8 Two distinct design strategies of incorporating visual cues to deviate the visitor from the existing route onto a diversion that promises to take the visitor near the visual cues. *Source* Author

Fig. 9 Benches along the Het Lint either exhibit visual engagement with the park pergola or exhibit a setting that does not afford any sensorial engagement. *Source* West 8

Fig. 10 Benches along the stroll routes sensorially engaged with the elements around it. *Source* Amaury Vermeire

be discussed as the ritualistic visitation is limited to only cyclists in the Vondelpark. Table 1 presents the comparative analysis between Vondelpark and Máximapark.

Table 1 Comparative analysis between Vondelpark and Máximapark for its Kinaesthetic experience

Attribute	Vondelpark versus Máximapark
Experience of stroll	Keeping true to its design intention of being an English landscape park, the Vondelpark presents an ideal experience of a stroll. In comparison, the Máximapark's attempt at inventing its own strategies of incorporating visual cues make the visitors feel that it is not a stroll, but in reality, there is the same control over their movement through visual enticement
Experience of ramble	Although users carve out their own rambling routes through the sprawling meadows in Vondelpark, it does not comprise of pre-defined paths for rambling. While Máximapark also accommodates rambling through the meadows, its layout is designed with pre-defined rambling routes that deviate from the strolling paths
Transition between movement patterns	The materiality of the routes in Vondelpark as rugged, dirt paths allow for a nonchalant transition between strolling on defined routes and rambling through open meadows. In contrast, the asphalt routes in Máximapark make this same transition a highly conscious one
Influence of visual cues on movement transitions	In the Vondelpark, the centrally placed meandering water feature entices a visitor to come closer, by deviating him from his stroll route into a ramble through the meadow. In Máximapark, the stroll route's designed proximity with the water features prevents such enticement for transitioning between movement patterns
Seating as a complement to the movement pattern	In Vondelpark, the seating has been incentivised as a visual cue, thereby grounding it to the park's design concept of being a stroll park. In contrast, the Máximapark uses seating in a purpose-driven manner, whereby seating is either to enhance walkability or to orient the visitor towards the opportunity for a sensorial engagement

4 Conclusion

The study of the urban parks for their routing articulation and kinaesthetic experiences validates much of Hunt's theory on movement patterns, along with providing substantial points of observations to enrich the theory further.

The first set of observations pertain to that of the ritual. It was realised that the routing in these parks did not fully fit the description that Hunt lays out for a ritualistic movement comprising of pathways "dotted with forms and elements that construct a narrative for the visitor to interpret." Although the design is based upon a certain spatial and visual concept with a specific vocabulary of landscape architectonic elements and material palette, there is no particular narrative for these parks to be interpreted perse. The reason for this difference can be traced to Hunt's focus mostly being on private, aristocratic gardens or religious spaces, during his elaboration of the ritual. Further, during the walking exploration of these parks, the experience of a ritualistic movement pattern was felt to be representative of routes that were rather restrictive in terms of freedom of choices. This can be held as an analogous understanding to Hunt's suggestion that sites for ritual are more structured, with an established pattern. In the case of both the parks, the cycle routes are the ones that exhibited a ritualistic movement pattern.

The second set of discussion belongs to the stroll. Hunt explains that the design for stroll keeps the walker to well-defined paths with invitations to push on; a strategy that has been employed in the articulation of pathways in the Vondelpark. However, the study of the kinaesthetic experiences in the Máximapark puts forth the possibility of broadening the conventional understanding of a strolling path. Máximapark illustrates how the design for strolling can also be curated by designing visual cues that instead of keeping the visitors on their existing route, entice them towards an alternate path. This strategy gives visitors the feeling of being in control of their choices, yet, in reality, they are being pre-dominantly controlled by the design influence of the visual cues.

When it comes to the movement pattern of a ramble, Hunt's description of the ramble fits in perfectly with the observations made on-site, in both the parks. The case studies particularly highlight the behavioural pattern of visitors using the sprawling meadow spaces as opportunities to ramble, especially in the summer months that see a large number of visitors to these public parks. This observation brings the realisation that either visibly through pre-designed pathways, or invisibly by providing open meadows to make one's own, accommodation of rambling into an urban park's design layout is crucial. This allows people to remember the park through their own, unique routing sights and experiences, along with guaranteeing that even the same visitor does not ramble along the same route the next time he returns to the park, thereby making the space interesting for the visitor, each time.

The study establishes the possibility of the different visitation patterns co-existing in our designed landscapes and thereby exuding varied kinaesthetic experiences. Additionally, the study of the parks exhibit the interactions that paths offering different movement patterns can have with one another. In both the cases, widths

of the routes have been used as a strategy to indicate the distinction in the intended visitation pattern. In cases such as the Máximapark where all routes have the same materiality, the effect of different widths to the kinaesthetic experience becomes very prominently recognisable. However, when the materiality of the paths is made distinct, in addition to different widths, as in the case of the Vondelpark, it is the materials that take the attention of specifying a change in visitation pattern. As the study demonstrates seating can also specify a change in visitation pattern through their design, orientation and degree of engagement with its setting. Furthermore, as seen in both the cases, the paths offering different visitation patterns do not have to be spatially and visually exclusive of one another. Paths for different visitations can arise from one another to diverge into the landscape at different moments along with the routing or pass alongside one another for certain stretches of the routing through the landscape.

The on-site observations have brought the realisation that each movement pattern has its own essence and there appears to be no reason to promote one movement pattern over the other. The composition between the movement patterns is best described by the typology and design intention behind the designed landscape, as can be understood from the case studies of the two Dutch urban park elaborated through this paper.

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Perception Shift Towards (Inter)personal Space: Public Transport and COVID-19 Pandemic

Vidushi Jaya and Sanjram Premjit Khanganba

Abstract The pandemic disrupted transportation by hampering people's daily lives, affecting people's perception towards their (inter)personal space (IPS) while traveling. The study analyzes the change in transport behavior of commuters on six parameters which are clubbed into three aspects, i.e., transport behavior in public space, in personal space, and towards others while travelling. These aspects provide in-depth understanding of the shift in perception towards IPS while traveling prior to lockdown experiences (PLE) and with lockdown experiences (WLE) in the world's second-most populous country. The study examines the overall change in perception towards IPS while travelling considering sanitation awareness, personal space while travelling, preference for a personal vehicle, skepticism towards public transport, attitude towards fellow passengers and blue-collar workers in the health and sanitation sector, as important contributors to shape perception in the pandemic times. The results suggest significant change in transport behavior on all three aspects affecting impression for fellow passengers as potential carriers of the virus, and poor perception of sanitation in public places. The skepticism towards public transport increased yet not the preference for personal vehicle as it is not possible for every commuter to afford one considering the effect the pandemic caused on the economic condition of people. Sanitation awareness in individuals' IPS heightened while travelling and being in public place. The inferences highlight the need for spacious and sanitized transportation and the need for trust-building measures to restore the faith of people

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in public transport. A major policy reform incorporating public health concerns is required.

Keywords Pandemic · IPS · Transport behavior · Sanitation · Public transport

1 Introduction

Out of everything India is known for, the second-most populous country (~1.34 billion) is usually the starting point when we talk about India [1]. Population plays a crucial role in understanding a group's socio-cultural norms and shaping perception of personal space in private and public spheres. As a hallmark of collectivistic society, families are closely knit as a unit, not only through emotional attachment but physical closeness as well. There is a prominent cultural orientation towards a joint family system where even three generations- parents, children, grandchildren, share the same roof and the ancestral affiliations are very strong as a collective unit. Apart from emotional attachment, sharing of space is also instigated owing to the economic status of many Indian families where children sleep with parents or share bed with other members of the family. Over 20th Century, Asian families started orienting towards staying nuclear because of non-family employment, rural–urban migration, and female employment [2]. Adults still support their parents through remittances and co-residence. Data from India's National Sample Survey [3] suggest that 87% of elderly widows and widowers live with their children. Many Indian families continue to maintain joint family structure as strong family bonds encourage family business which strengthens family ties [2]. Also, housing costs make it difficult to live alone. Extended families are more common in many middle and low-income countries. Ruggles and Heggeness [4] reported no general decline in generations of families staying together based on census data for 15 developing countries.

1.1 Proxemics and Social Behavior

As social beings, the perception of space is integral to our behavior, communication, and understanding of culture and social conduct. In the current context, understanding the aspects of proxemics is important. Proxemics deals with IPS, which refers to an imaginary distance zone around the body's circumference which people maintain in social spheres. Its intrusion leads to discomfort. The spatial extent of IPS varies across culture, and its boundaries are regulated and constantly negotiated according to the context and emotional states of individuals. For instance, IPS may reduce after a cooperative social interaction or induce a positive emotional experience. Also, cultural nourishing and population play a decisive role in establishing the notion of IPS. In India, craning one's neck close to the ears of the person standing next to in

a queue, talking loudly on phone while traveling, pushing someone to get into or to come out of any vehicle, getting up from the seats as soon as the flight lands and paving the way out of crowd is commonly observable. Collectivistic communities have the habit of living in clustered spaces with neighbors or other people outside their core families without feeling threatened [5]. In everyday life, space is used together with other family members to create a socio-petal space that increasingly holds family members together. In their daily lives, community members are accustomed to completing work together. If they live in extreme natural conditions, each group member will try to protect each other and discuss their resolution in their collective spaces. In fact, in some settings, breaching personal space boundaries are considered friendly, like sharing food on the same plate or putting colors during the festivals. It is usually not considered inappropriate; instead, it is a part of the ethos and a symbol of bonding even to the strangers.

The notion of personal space manifests differently in the Indian setting unlike western countries where personal space invasion is considered a severe threat. In the Indian system, 'adjusting' is the norm, and maintaining too much physical distance from people is usually considered a social anomaly because physical proximity is integral to a collectivistic society contrary to the independent individualistic society where personal space is well guarded [6]. It is not the impropriety but the nation's socio-cultural ethos, which is also associated with the problems like facilitating the spread of infectious diseases.

1.2 Public Transport

The rapid growth of India's urban population has put enormous stress on all transport systems. The stress manifests as both external and internal. External stress is the on-road congestion (as a significant share of the public transport systems are road-based) and internal congestion is the overcrowding of people within the vehicle.

Burgeoning travel demands far exceed the limited supply of transport infrastructure and services. In particular, public transport systems (trains, buses, metro, etc.) constantly face the challenge of the inability to accommodate the overwhelming number of travelers. The hassle of getting a train seat reserved is inevitable if the journey was not planned a few months ago. The problem becomes monstrous during festive seasons where lakhs of students and workers residing in other cities for better education and salary respectively take a turn towards their homes.

According to data from Indian Railway, the passenger traffic in the railway sector amounted to over eight billion across India in the fiscal year 2019 [7]. An overloaded bus or train where people sit inside as well as on the top of it and are jam-packed on aisles and near gates to travel is not uncommon. Considering the population, shortage of public transport, and congestion while traveling, the vehicles are overused than their carrying capacity, and the distance between people becomes negligible. The scene is like stampede due to rush to get a seat as soon as the train or bus arrive. People scuffle to get in and out of the vehicle facilitating situations leading to injury.

People stuffed near gates of buses and train to travel is unpleasant but not uncommon sight in India. The problem of compliance issue is another major problem where people do not follow traffic rules or put on ineffective protective gears like helmets, handkerchief masks only to avoid the penalty and not for their safety concerns. This negative perception of the authority where commuters feel threatened rather than being supported and safe is a sign of unhealthy relationship between the two leading to unwarranted ideological and physical conflict.

1.3 Pandemic and Transport

The COVID-19 outbreak [8] compelled people to make significant changes in their lifestyles and social behavior in the public sphere, predominantly while traveling. It paved the way to a social restructuring where physical distancing is the only way to keep people, public space, and transport safe.

Given the cultural upbringing of mainland Indians and the expanding population, the notion of IPS becomes unrealistic as it is nearly impossible to maintain social distance in public transport vehicles. The overcrowding in public transport and on stations due to delayed trains and overwhelming numbers of passengers who need to travel for work purpose makes social distancing a challenging task. Congested trains and buses serve a nourishing and thriving environment for the infection to spread quickly as the IPS is minimum to insignificant where people are jam-packed. The arrival of pandemic makes the public transport a worst place to be in and the least preferred option to choose to travel. One can contract virus effortlessly while travelling in any of the public transport vehicle where people themselves are negligent about the safety of themselves and others. A sense of denial of not getting infected as well as ignorance to take precautionary measures like wearing mask properly, maintaining social distance, carrying a spray sanitizer, and using it frequently, leads to spread of infection. In such a critical time, where infection is just a trip away makes kids and older people susceptible victims, and adults tend to become asymptomatic carriers in most cases. Any fellow passenger can be a potential carrier which might lead to a sense of hostility and negative perception of the travelers. This can lead to a major shift in perception towards fellow passengers and the way one sees one's personal space in public spheres.

A persistent negative attitude towards others has the potential to affect people's helping behavior too as they tend to avoid physical contact with others. This pandemic has challenged the social norms of IPS, and transportation is a significant area which carries the aftereffects of this change in perception towards IPS. The study is designed to investigate this change of people's perception towards IPS and their changing behavior while travelling. It is hypothesized that due to the ongoing global health crisis, people would become more perceptive of their personal space and this will lead to significant behavioral change while travelling.

2 Methodology

2.1 Participants

Respondents voluntarily participated in the study. Despite the investigators' efforts to engage larger pool of respondents, there were 25 individuals, aged, 21–31 years ($M = 26.28$; $SD = 2.92$; 14 males and 11 females) who completed the online survey. Many potential respondents could not confirm their participation due to their pandemic related situations.

2.2 Materials and Procedure

The participants were first contacted online and explained about the study. After establishing the required rapport at their convenient time and after obtaining their consent, the online questionnaire was sent. Once they responded, they were contacted on the phone based on prior arranged schedule, and a telephonic interview was conducted probing open-ended questions in order to gain more insights concerning their responses registered through online questionnaire. This step also served as debriefing session for the respondents in which the interviewer answered to their queries. The primary benefit of this step was that the interviewer and the respondents had in-depth discussion, as the interaction progressed. The respondents were given the flexibility and liberty to share their personal experience and opinions as well.

To study the perception shift towards IPS and transportation prior to lockdown experience (PLE) and with lockdown experience (WLE), a self-report questionnaire (see Appendix) was developed, namely, (Inter)Personal Space Transport Behavior Questionnaire (IPSTBQ). This questionnaire is comprised of 25 items including 8 negative items as well in order to attenuate response pattern bias (primarily reducing extreme response bias and acquiescent bias) [9]. The items are related to the three aspects of transport behavior, i.e., (i) Transport Behavior in Public Space, (ii) Transport Behavior in Personal Space, and (iii) Transport Behavior Towards Others. These three aspects were studied using two parameters each, i.e., six parameters in total viz. (i) Sanitation awareness (SA) (3 items) (ii) Skepticism towards public transport (STPT) (4 items), (iii) Personal space while traveling (PSWT) (4 items), (iv) Preference for a personal vehicle (PFPV) (4 item), (v) Attitude towards blue-collar workers (ATBCW) (5 items), and (vi) Negative impression for fellow passengers (NIFP) (5 items).

The participants were asked to rate their prior to lockdown experience (PLE) and with lockdown experience (WLE) while travelling during COVID19 times on a seven-point scale (ranging from 1- Completely Disagree to 7- Completely Agree). 40 people participated in the survey, out of which 25 completed the survey till the end. Two subjective items were included in the end for better insights. For online

data collection, the platform PsyToolkit. It is a free-to-use toolkit for demonstrating, programming, and running cognitive-psychological experiments and surveys [10].

3 Results

To examine the perception of IPS in the context of COVID-19 pandemic [8] while travelling, the survey was conducted to collect behavioral samples regarding PLE and WLE. Paired sample *t*-tests were performed for six parameters to examine the significance level of difference between the means of respondents' change in perception towards IPS prior to lockdown experience (PLE) to with lockdown experience (WLE) on three aspects of transport behavior, i.e., in public space, in personal space, and towards public. The analysis showed significant perceptual change from prior to lockdown condition to with lockdown experience on multiple parameters. To infer statistical significance, an alpha level of $P \leq 0.05$ was considered.

There is significant change in perception towards IPS for PLE versus WLE on four out of six parameters, i.e., NIFP (PLE) ($M = 3.528$, $SD = 0.522$) versus NIFP (WLE) ($M = 5.552$, $SD = 0.348$), $t(24) = 7.738$, $p = 0.002$ and SA (PLE) ($M = 3.160$, $SD = 0.312$) versus SA (WLE) ($M = 5.88$, $SD = 0.174$), $t(24) = 19.630$, $p = 0.003$., PSWT (PLE) ($M = 3.190$, $SD = 0.709$) versus PSWT (WLE) ($M = 5.580$, $SD = 0.858$), $t(24) = 3.178$, $p = 0.050$, and STPT (PLE) ($M = 3.900$, $SD = 0.859$) versus STPT (WLE) ($M = 4.440$, $SD = 0.567$), $t(24) = 3.146$, $p = 0.051$. The values on other two parameters were not significant, i.e., PFPV (PLE) ($M = 4.150$, $SD = 0.783$) versus PFPV (WLE) ($M = 4.630$, $SD = 1.132$), $t(24) = 0.512$, $p = 0.644$, ATBCW (PLE) ($M = 3.044$, $SD = 1.447$) versus ATBCW (WLE) ($M = 3.39$, $SD = 0.653$), $t(24) = 0.655$, $p = 0.548$.

The results indicate that there is a shift of perception between prior to lockdown and with lockdown experience (Fig. 1). Apart from the survey, participants were also given two subjective items—(1) What major changes have you observed in transportation during the pandemic? and, (2) Suggestions to improve hygiene in public places and public transport? To the former they responded a heightened sense of personal hygiene, fear of unknown people in public places, increased preference for a private vehicle, avoidance of unnecessary travels, and increased social distancing. The responses suggested for the second items included regular checking at different stops to monitor the number of people boarding a public vehicle, providing hand sanitizer at public transport and public places, use of internet banking or token system to avoid transacting through cash which will lead to lessened contact between a driver and passenger. Also, making mask-wearing compulsory to avail entry in public places or transport, spreading awareness among the public, cleaning the public places frequently, installing sanitizer booths at multiple places, and avoiding physical contact and spitting in public places. Vehicles should be disinfected on a regular basis and the driver should be examined clinically on a regular basis.

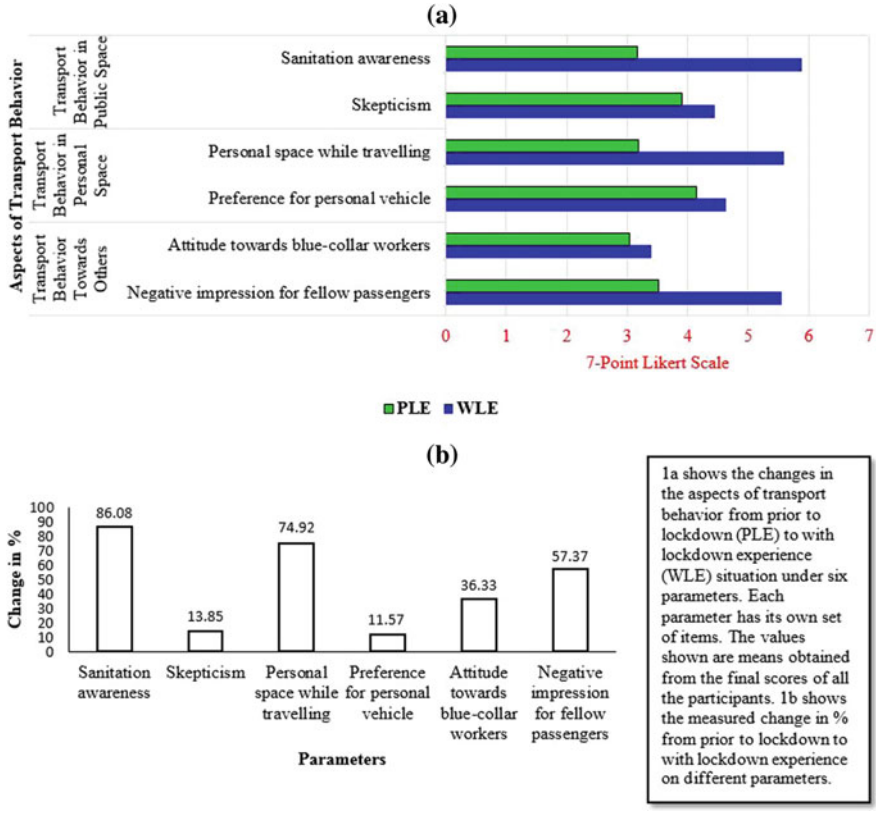

Fig. 1 Change in transport behavior prior to lockdown and with lockdown experience

4 Discussion

Owing to the COVID19 pandemic, the society went through some drastic changes in their way of living, working, and interacting with the people. Travelling was hampered and reduced due to limited availability of transport vehicles [11]. The pandemic times gave a dynamic push to the culture of 'work from home', be it online classes, lectures, or meetings [12]. The office desks shifted to dining tables, formals turned into pajamas, and with that changed our perception towards IPS.

Results indicate that there is a significant shift in people's perception towards the IPS *with lockdown experience* (WLE) as compared to *prior to lockdown experience* (PLE), given the fear of contracting the infection. This in turn has increased respondents' negative perception of fellow passengers as potential carriers, and they actively maintain social distance while traveling. This indicates the change in *Transport Behavior towards Others* on one of the two parameters, i.e., NIFP. There is significant change in the SA of people as they use masks and sanitizer frequently in public space and do take others' cleanliness into consideration while travelling.

This shows the changing *Transport Behavior in Public Space* as well as *Transport Behavior towards Others.* It also altered our physical bonding to the community as there is a reduction in sharing the sitting space in the vehicle and avoiding sharing cars and bikes as indicated by PSWT suggesting change in *Transport Behavior in Personal Space* though no significant change in the PFPV which may be due the economic condition of people as they find public transport affordable. The change in all three aspects of *Travel Behavior (Public Space, Personal Space, Towards Others)* is with respect to the necessity of the pandemic situation where there is significant travel avoidance given the knowledge of the spread of infection [13]. Counterintuitively, the non-significant difference on the parameter ATBCW shows a positive side as people do not discriminate the blue-collar workers from the health and sanitation sector considering they are easy prey for infection and can be significant potential carriers. This positive attitude towards health care workers during these critical times shows a sense of support and unity which symbolizes collectivistic society. There have been cases of violence against health workers where they became targets of public fury [14] but the Government's instant actions of making amendments in the outdated laws [15] and people's awareness, and unity reversed the hostility quickly and restored the positive perception. Unfortunately, people's perception of safety, sanitation, and hygiene towards public transport remains negative as of prior to lockdown. They find a lack of cleanliness in the public vehicle, and their preference for owning vehicles increased due to lack of trust in public transport.

5 Conclusion

The study concludes that there is a significant shift in people's perception towards their IPS, and they are more concerned about the sanitation and hygiene of the vehicle and fellow passengers while travelling. The pandemic has brought challenges faced by people and the opportunity to rethink our travelling behavior and incorporate necessary changes to suit public health and hygiene. As transportation is a crucial part of our lives irrespective of the presence or absence of the pandemic, it is essential to make transportation safe and secure from all possible physical and biological threats. The psychological wellbeing of the traveler is also of utmost importance where one can have a sense of security while travelling using various modes of transport, without fearing that someone's presence nearby is a threat. In the current situation, vaccine passports [16] are a suitable option tested in many countries to facilitate secure transportation. Public awareness about IPS is vital while dealing with such a critical situation, and it is evident that it changed the perception as the pandemic took over. The study suggests the need for major policy reforms and lifestyle changes required to make transport convenient. It is also to be taken care of that this perception shift does not lead to an unfriendly or aggressive attitude towards fellow passengers, and our helping behavior remains intact. The pandemic showed the frailty of human lives in front of a microorganism, and it is time we learn our lessons.

Future studies can explore the effect of socioeconomic condition, gender, and urban–rural habitation for better understanding of Transport Behavior aspects on parameters.

Acknowledgements The authors thank the respondents who extended their support in the study by sharing their personal experiences. Vidushi Jaya and Sanjram P. K. share equal contribution as co-first authors.

Appendix

(Inter)Personal Space Transport Behavior Questionnaire (IPSTBQ)

Transport Behavior in Public Space

1. Sanitation awareness (SA)

    1. Do you use sanitizer frequently?
    2. Is it upsetting that people around you do not wear mask?
    3. Is it upsetting that people around you do not use sanitizer frequently?

2. Skepticism towards public transport (STPT)

    4. Do you prefer public transport over using your own vehicle?
    5. Do you think they are safe to travel in the time of pandemic?
    6. Considering sanitization, would you prefer train or flight to travel?
    7. Do you think public transport vehicles are clean?

Transport Behavior in Personal Space

3. Personal space while travelling (PSWT)

    8. Do you prefer to pool cab?
    9. Do you prefer an unknown passenger sitting next to you while travelling?
    10. Do you wear mask when people are around?
    11. Do you maintain distance as much as possible while travelling?

4. Preference for a personal vehicle (PFPV)

    12. If you purchased own vehicle due to pandemic?
    13. Is it better to have personal vehicle instead of using public transport?
    14. Do you share your car/bike with someone else?
    15. Do you clean your car/bike if someone else has used it?

Transport Behavior Towards Others

5. Attitude towards blue-collar workers (ATBCW)

    16. Do you avoid being around health care workers and sanitization workers?
    17. Do you fear they may not be clean and hygienic?
    18. Are you apprehensive they are the carriers?
    19. Do you think it is not safe being around such people during the pandemic?
    20. Have you ever been harsh on such people because they were standing/sitting very close to you?

6. Negative impression for fellow passengers (NIFP)

    21. Do you feel insecure if traveler's hygiene standards do not match your expectations?
    22. Do you fear that people around you might be carrying the virus?
    23. Do you actively try to make distance from people?
    24. If you avoid physical contact with people?
    25. If other's general touch make you feel uncomfortable?

Rating and Scoring: Items are to be rated on 7-point Likert Scale ranging from 1-Completely Disagree to 7- Completely Agree. All the items are to be given scores of 1–7 as per the response, i.e., 1 score if the rating is 1 (Completely Disagree), and 7 score if the rating is 7 (Completely Agree) except items from 4 to 9, 14, and 15 which are negatively scored, i.e., 1 score to be given if the rating is 7, 2 for 6, and so on. Final score on each parameter is obtained by adding scores of the items and calculating mean scores under the respective parameter.

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Game Addiction and Game Design: A Study Based Candy Crush Saga Players

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Abstract The emergence of mobile social games has increased the number of casual game players, allowing researchers to better understand the relationship between Internet gaming addiction and psychological factors among players. However, other factors such as game design must also be considered. The aim of this study is to learn how design factors like operant conditioning, game play, game design, isolation, cheating, and Nash equilibrium are linked to game addiction using Candy Crush Saga as the casual game. A questionnaire was distributed to Candy Crush Saga players to learn more about demographic characteristics, gaming addiction scale, and game design. A total of 206 responses were obtained from people aged 18 to 65. Data was gathered, and a multivariate statistical analysis was carried out. The findings of this study revealed that there is a connection between male and female addicts' professions. Several aspects of gaming are identified in the paper as contributing to adult gamers' addiction. We discovered that some aspects of Candy Crush entice players to use it as a mood enhancer. The HCI Contextualize! Personalize! Persuade! framework was used to suggest a solution. Or the CPP framework, which was created to track addiction via a behaviour change support system in Candy Crush and other gaming applications.

Keywords Gaming addiction · Game design · HCI · Casual gamers

1 Introduction

The increase in smartphones and connected mobile devices has introduced a unique platform for social gaming [1]. Mobile social games can be defined as casual games that can be played on digital devices for pleasure by connecting on social media networks [1]. Where casual games are the games with simple game controls and fewer complications to complete the game [2]. Candy Crush Saga is one of the popular mobile social games introduced by King Digital Entertainment in 2012, becoming a sensation by attracting 93 million regular players and 500 million installs

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on mobile devices. It is a match-3 puzzle in which players match candies in combination of three or more to complete the levels [3]. Classification of Internet Gaming into addiction has always been debatable (APA, 2019). Internet gaming addiction being a behavioural problem includes various components such as salient behavior, mood modification, development of tolerance, symptoms of withdrawal, development of interpersonal and intrapersonal conflicts, and relapse [4]. Thus, with the increasing number of casual game players and the recent consequences of addiction, we see the need to assess the situation in India. There is evidence to suggest a relationship between gaming addiction and psychological factors. However, continuous reward loops or ludic loops are what attracts these games. Ludic Loops are continuously satisfying feedback loops that cause repetitive behavior. These results have been derived from studying slot machines and their temptation towards addicts. These loops tempt players into short cycles of repeated actions by using behavioral psychology of doing something and responding by giving rewards so that players do it again [5]. However, more focus needs to be drawn towards the design factors which contribute towards ludic loops on digital gaming platforms. The present study aims to focus on understanding design factors such as operant conditioning, game play, game design, solitude, cheating and Nash equilibrium and how they can be associated with game addiction taking Candy Crush Saga as the casual game being played. The objective of the study is to understand game addiction amongst Candy Crush Saga players and their relationship with gaming addiction scale and design variables. Also to observe the link between game design and demographic characteristics and provide a suitable solution for gaming addicts.

1.1 Hypothesis

H01—There is no significant difference in Gaming Addiction Score between male and females.

H02—There is no significant association in dislike of animation at the end of the level and addiction.

H03—There is no significant association in color combination of the game and addiction.

H04—There is no significant difference in aiming at receiving 3 stars among addicts and non-addicts.

H05—There is no significant difference in motivation by challenges in the game among addicts and non-addicts.

H06—There is no significant difference in likeness towards the theme of the game among addicts and non-addicts.

H07—There is no significant difference in likeness towards being alone during the game among addicts and non-addicts.

H08—There is no significant difference in restarting the level due to arrangement of the jellies among addicts and non-addicts.

H09—There is no significant difference in dislike towards completing levels in less than 10 moves among addicts and non-addicts.

2 Related Works

The *DSM-5* (diagnostic statistical manual of mental disorder) published by the APA (American psychiatric association) notes the following symptoms of internet gaming disorder. Preoccupation, Withdrawal, Tolerance, Inability to reduce playing, Giving up other activities, Continuing to game despite problems, Deceiving family members or others about the amount of time spent on gaming, The use of gaming to relieve negative moods & Risk, having jeopardized or lost a job or relationship due to gaming. Experiencing 5 or more symptoms in a year categorises an addict, the difference between a passionate and pathological gamer is the "significant impairment or distress" in several aspects of their life (2018, June) [6, 7]. Studies have shown that Internet gaming addiction appears to be associated with a variety of personality traits, which can be summed under the characteristics of introversion, neuroticism, impulsivity, self esteem and self control [4, 8] (Sanyal et al. 2016; Soroush et al. 2014). Motivations related to dysfunctional coping from stress, fear, escape, with intrinsic motivation like loneliness, boredom, leisure, socialization and personal satisfaction serve as a risk factors for developing Internet gaming disorder [4, 8, 9]. Well constructed games have a higher addiction scale than those which do not, especially those games that are masters in conditioning players through rewards. Studies also demonstrate the link between gaming disorder and physiological, biochemical and neurological aberrations [4] Gender differences in early studies showed males were more inclined towards addiction. Motives for playing, females enjoyed the challenge, exploration, collaboration and fantasy of a game and males enjoyed achievement, competition and social contacts [10–12]. According to Quantic Foundry in 2017 70% audience for family/farm simulators and match 3 games are women. The Entertainment Software Association (ESA) released 2019 Essential Facts that reported 34 the average female gamer age and 32 the average male gamer age. One comparative study in India reports middle aged women scoring more than younger women [9]. With fewer articles on design and addiction certain features such as narrative, aesthetics, character, interface and interaction of a video game have been associated with addiction. Addicted players are proud of their avatars or characters in games, they tend to like their characters more than themselves. They have a tendency to disassociate and immerse in games. The content drives them to keep playing. Most importantly reinforcing reward loops have an emotional effect on addicted players especially in multiplayer games [4, 13]. Through the literature we were able to understand game

addiction, it's cause, symptoms and factors that play a role in addiction. However the following **gaps and questions** for study were identified: **RQ1—**Studies have majorly focused on psychological factors, but what are the design and psychological factors in mobile games that contribute to a ludic loop, are they associated with addiction? Can these factors help guide game designers? **RQ 2—**There is a gradual yet dramatic increase of female and older gamers, studies regarding the same are limited. Hence, is there a difference in addiction between women and men? How do they vary between age groups?

3 Methodology

3.1 User Survey

User survey was conducted by developing a structured semi integrated questionnaire used to collect data to understand gaming addiction and ludic loop based on candy crush saga.

3.1.1 Tools

Following the results of the pilot study, the questionnaire was further edited using google forms consisting of 53 questions under 14 constructs. The form was divided into 3 sections. The first section consisted of general demographics questions related to age, gender, nationality, relationship status, occupation and profession, it also included basic gaming questions related to platform usage like "mobile, tablet or desktop", frequency of playing, current gameleve, how long the respondent plays in a day and how long has it been since they first started playing candy crush saga. The second section consisted of the complete Gaming Addiction Scale (GAS) by Lemmens (2009) that included 3 questions in 7 constructs, which were: salience, tolerance, mood modification, relapse, withdrawal, conflict and problems. The scale was designed to assess gaming addiction based on the DSM-5 criterias. Responses were recorded on a 5 point likert scale (never, rarely, sometimes, often and very often). The third section consisted of 21 statements that participants had to respond on a 5 point likert scale from strongly agree, agree, neutral, disagree & strongly disagree. The statements were related to ludic loop under 7 constructs such as operant conditioning, game play, game design, solitude, cheating, nash equilibrium and dopamine effects. The complete questionnaire can be found in the appendix section of the paper. The e-questionnaire/e-form was then circulated through various social media platforms using a combination of random and snowball sampling technique. Whatsapp messenger was used to send it to participants who were candy crush players or knew players and were asked to forward it further to other known players. A post was drafted to request responses mentioning the purpose of the study which was sent

Table 1 Demographics statistics

Variable	Value	N = 206	Percentage (%)
Gender	Male	59	21
	Female	147	79
Relationship status	Married	101	49
	Single	72	35
	Divorced	1	0.004
	Dating	32	15
Profession	Working	114	55.4
	Non-working	92	44.6
Age	18–40	127	61.65
	40–62	79	38.34
Occupation	Student	46	22.3
	Home-maker	36	17.4
	Working	124	60.2
Nationality	Indian	127	61
	American	45	22
	Others	24	17

across facebook groups such as candy crush saga, candy crush saga active friends, candy crush soda saga and r/candycrush on reddit. 206 Responses were collected using google sheets (Table 1).

4 Results

4.1 Gaming Addiction Score

Scoring was done according to the Gaming Addiction Scale (GAS) by Lemmens (2009). A total of 38 addicts were identified out of 206 respondents, 82% were (31) were females and 18% males (7). 47% (18) were married, 55% (21) were not working, the average age was 38, 82% were Indians, 89% (34) played on mobile phones, 60% (23) played daily the average playing hour was 2.5, the average level was 1542, lowest was level 7 and highest was level 6726. The average years of playing is 2.8, 2 months was the least and 8 years being the longest period.

Table 2 KMO and Bartlett's test

KMO and Bartlett's test		
Kaiser–Meyer–Olkin measure of sampling adequacy		0.830
Bartlett's test of sphericity	Approx. Chi-Square	2816.097
	df	378
	Sig.	0.000

4.2 Factor Analysis

Table 2 shows the Kaiser–Meyer–Olkin Measure of Sampling Adequacy and Bartlett's test of sphericity which indicate the suitability of data for structure detection. The KMO value indicates the proportion of variance in the variables. The value obtained here is 0.830 which is close to one indicating that a factor analysis may be useful for the data. According to Bartlett's test of sphericity, small values (less than 0.05) of the significance level indicate that a factor analysis may be useful with the data and the value obtained here is 0 which leads us to factor analysis of the data. In order to reduce the data by removing redundant variables and examining the underlying relationship between the variables, factor analysis is used.

The leftmost section of this Table 2. shows the variance explained by the initial solution. Only 7 factors in the initial solution have eigenvalues greater than 1. Together, they account for almost 67% of the variability in the original variables suggesting that there are 7 latent influences but a lot of unexplained variation still remains. The first factor solution revealed multiple factor loading so rotation is applied in an effort to find another set of loadings that fit the observations equally well but can also be more easily interpreted by using the varimax criterion. After five iterations of the rotation matrix, 28 variables are obtained divided under seven factors as Game Play 3, Operant Conditioning 2, Game Play 2, Game Play 1, Operant Conditioning 3, Game Design 4, Game Design 1, Solitude 3 under Positive Reinforcement; conflict 1, conflict 2, conflict 3, problem 1, problem 2, problem 3 under Problem Gaming; tolerance 1, tolerance 2, salience 2, salience 3 under Tolerance; withdrawal 1, withdrawal 2,withdrawal 3, problem 3 under Withdrawal; mood modification 2, mood modification 3, game design 6 under Mood Modification; cheating 1, cheating 2 under Cheating; and relapse 1 and tolerance 3 under Relapse respectively. The values range from -1 to $+1$ where the selection criteria for variables under each factor was it's value being greater than 0.5 and each factor containing more than one variable.

4.3 Hypothesis Testing

(See Tables 3 and 4)

Table 3 Differences—demographics and addiction

Differences—demographics and addiction		
Hypothesis	Test	*p* value
H_{01}	Mann–Whitney	0.004

Tabel 4 Hypotheses

Game design variables		
Variable	Test	*p* value
Game Design 2	Chi Square	0.019
Game Design 6	Chi Square	0.025
Operant Conditioning 3	Mann–Whitney	0.033
Game Play 1	Mann–Whitney	0.021
Game Design 1	Mann–Whitney	0.041
Solitude 2	Mann–Whitney	0.003
Cheating 2	Mann–Whitney	0.01
Dopamine 1	Mann–Whitney	0.016

5 Design Intervention

The WHO (World Health Organization) suggests "people who partake in gaming should be alert to the amount of time they spend on gaming activities, particularly when it is to the exclusion of other daily activities, as well as to any changes in their physical or psychological health and social functioning that could be attributed to their pattern of gaming behaviour". Primary recognition of gaming addiction happens by self monitoring. Existing methods of self monitoring for causal mobile games include screen time, google wellbeing and other wellbeing applications that track time spent on apps and allows you to set reminders. These methods work well for parents monitoring their kids but when it comes to adults they will need more motivation. We're proposing a monitoring system inherent in games based on the CPP model. CPP (context-aware, personalised, persuasive) is a A System Design Framework for Contextaware, Personalised, and Persuasive BCSS (Behaviour Change Support Systems).

5.1 CPP Based Monitoring System

"The CPP framework: A Layered Approach The suggested framework operates on and between three layers (see Fig. 1 for a graphical representation). First, on the target behaviour layer, a BCSS implements a number of persuasive strategies. Next, on the user layer, it personalises its services. Finally, on the situation layer, it adjusts to a specific context. The selection of strategies, personal, and context variables needs to

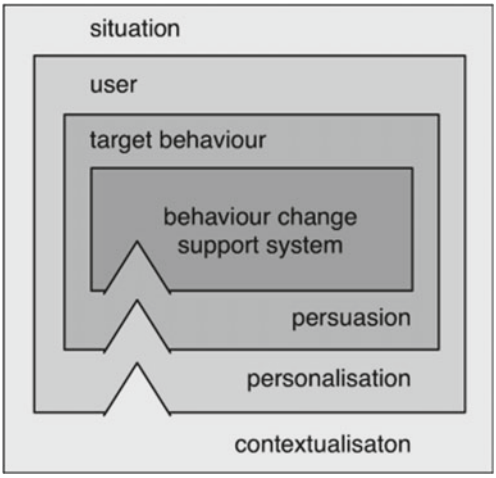

Fig. 1 CPP framework [21]

Table 5 Monitoring system framework features and factors

BCSF	Suggested features
Contextualisation	
Daily statistics	On hours played for the whole week split date wise is displayed
Ludic loop	Utilises the information from os self monitoring systems to check the total time spent on the smartphone. Mentioning the intervals from one app to another
Warning/suggestions	Warning of exceeding time limits, excessive gaming without intervals, suggestions to set reminders
Fitness apps	Tracks physical activity moments to monitor wellbeing
Personalisation	
Persuadability	Monitor initial persuasive tactics through machine learning
Push notifications	Opt for push notification for reminders on selective features
Customise	Customise the time intervals according to daily routines
Persuasive strategies	
Feedback & monitoring	Feedback on progress and daily statistics
Suggestions	Suggestions on improvising limits/
Negative reinforcement	Reduce game scores, lock levels or deduct lives
Positive reinforcement	Increase game scores, get extra lives, extra features and unlock next levels
Social comparison	Compare progress with other gamers on social media or personal contacts

be based on the system's application domain" [21]. Table 5 describes the behavior change support factors (BCSF) that interlink the situation, user and target audience layers. The behavior change required is to set limits to gaming in intervals rather

than excessively playing for hours. Whether a player needs to change their habits is primarily monitored by the contextualization factors that have Daily Statistics, Ludic Loop, Warning/Suggestions & Fitness apps factors. To follow through a change the system provides persuasion factors like Feedback & monitoring, Suggestions, Negative reinforcement, Positive reinforcement and social comparison. These factors are personalized by Persuadability, Push notifications & Customise factors.

A player would require a change in playing pattern if they're playing more than 4 h daily and continuously for a complete week, if they do not take a break from smartphone engagement and switch between apps without enough intervals and have poor physical activity. Warnings and suggestions are displayed to the player to use the customise feature to set limits to playing. The notification alerts can be customised, sounds can be set, alerts for reminders can be chosen. Machine learning is used to see if the persuasive tactics are working and which ones are working better than the others. Persuasive strategies include increasing game scores, extra lives, extra features & unlocking next levels for following through set limits. Reduce game scores, lock levels or deduct lives for not following through limits and continued excessive gaming. Feedback & progress is monitored, the player can also choose to link their social media or contact lists to compare progress. Prost, S., Schrammel, J., Röderer, K., & Tscheligi, M. (2013, August). Contextualise! Personalise! Persuade!

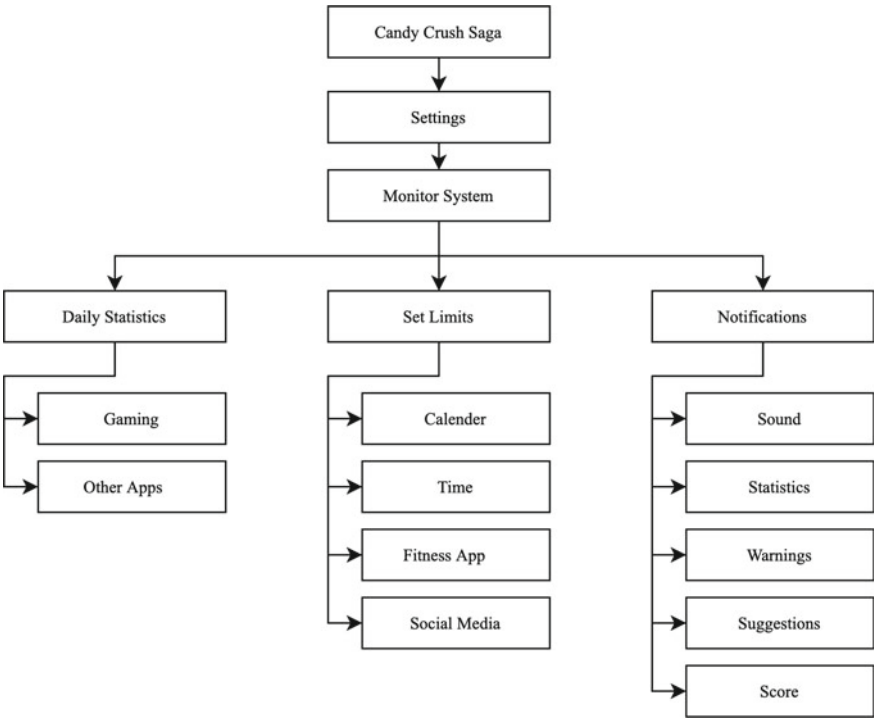

Fig. 2 Information architecture of the monitoring system

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6 Discussion

Through the study we were able to identify that design aspects of gaming addiction had fewer research and even amongst the ones that were available none of them focused on casual games. Thus, providing us the opportunity to focus on the design aspect of addiction. So far, age based addiction tests were mostly conducted on adolescents. There was fewer research on adult gamers and addiction. Where existing studies showed us that female casual gamers are more than males but through our research we were able to confirm that adult female players of casual games are prone to addiction more than adult males, especially non-working adult. Through our research we were able to confirm that adult female players of casual games are prone to addiction more than adult males, especially non-working adults. The highest factor loading is positive reinforcements that consisted of a blend of the design variables. Thus, we were able to reaffirm that positive reinforcement aspects of a game like challenges, tougher levels, uncertainty of the next level plays an important role in engaging users especially in an endless game such as candy crush but additionally findings show that these features play a role in addiction as well [4]. The second highest loading factor is problem gaming, most users have faced conflict with friends, family, neglected work and have faced sleep deprivation due to gaming. Regardless of the symptoms the next factor tolerance points out that they spend most of their time gaming and eventually get hooked that they feel stressed, angry and bad when they're unable to play but feel neglect the time spent as pointed out in the withdrawal factor. We have noticed that having an engaging theme, encouraging compliments with pleasing color schemes lure players to use the game as a medium to release stress, and feel better to modify their moods which is in line with the findings of Kuss and Griffiths about well constructed games and depicts why the factor mood modification is the only factor which is a blend between the addiction and design variables. However, results also show that addicts of these games use forms of cheating like changing the dates on their phone or refreshing their games when they do not like the arrangement of the jellies as mentioned in the cheating factor to satisfy their urges. In the last factor relapse points out that users were unable to reduce their game time and cannot stop playing once they start. Hence unlike existing solutions there is a need to help users monitor and take control of their gaming sessions through the game. The proposed design intervention provides a means for preliminary behavioral change factors to be considered for a game using an already validated framework. These features are inherent and are linked to the game's rewards functionalities. Allowing companies to ethically run a company and keeping their customers healthy whereas existing design interventions are not directly linked to the game but are external features that warn users.

7 Conclusion

We were able to achieve our objectives, understand our research gap and maintain the novelty of the paper by establishing a relationship between design variables and internet gaming addiction specific to candy crush. A qualitative research can also be conducted since there is a possibility that players may have been dishonest in the survey. There is scope to identify more variables of design not just specific to candy crush but other top casual games which can be identified with gaming addiction and to study dopamine withdrawal, conduct experiments during gaming to understand the scientific aspects of addiction. There is scope to study the data according to different age groups. These further research can help identify an intervention for gaming addiction. Future scope includes designing and developing the proposed system.

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Impact of Acoustic Distraction and Overcrowding on Cognitive Performance of Healthcare Professionals

Abhijit Kakati and Amarendra Kumar Das

Abstract Overcrowding and acoustic distraction often affect the cognitive performance of healthcare professionals. They often find it very disrupting and challenging to focus on their tasks because of the chaotic work environment. Health camps are a time-constrained affair, and the healthcare experts have no control over the work environment. They face a higher rate of interruption in the health camps when compared to their usual clinical settings. These trigger a sense of anxiety in their already demanding workload. The current research investigates how overcrowding and acoustic distractions escalate cognitive load among healthcare professionals. A field study was carried out in seven (07) different health campsites, and the perspectives of Thirty-seven (37) healthcare professionals were captured. A walkthrough survey, interview, and questionnaire were used in the study. Most of the respondents mentioned that they undergo intense stress and distraction due to the demanding nature of work at the health camps. Congestion of the patients at the health camps and acoustic distractions hampers their ability to work optimally. Lack of patient management system and uncontrollable physical work environment disrupts the professionals throughout the health camp. The results provide insight into how acoustic distraction and overcrowding at the health campsites act as barriers to imparting safe and high-quality healthcare. Interventions aimed at reducing the cognitive load and increasing the efficacy of the healthcare workers have been proposed to overcome these barriers.

Keywords Cognitive performance · Acoustic distraction · Overcrowding · Health camps · Cognitive load

1 Background

Health professionals deployed in health camps have to deal with many patients in a single camp, and the probability of patient outcome error resulting from distraction

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and interruption escalates. The cognitive, psychological, and organizational features are directly related to the quality of care [1]. Healthcare professionals are exposed to several work factors that add to their working stress. A few of these factors include the acoustic condition of the health setting, overload, crowding of the patients at the health setup, lighting conditions, temperature, etc. The intensity increases at health settings like the rural health camps. Health camps are a time-constrained affair, and the healthcare experts have no control over the work environment. They face a higher rate of interruption in the health camps when compared to their usual clinical settings. These trigger a sense of anxiety in their already demanding workload. Increased workloads, like in the healthcare sector, are often considered much suitable when the employee has control over their work and the work environment. The presence of auditory distractions in a work environment burdens the information processing system and declines the cognitive performance capability at the workplace [2]. The distraction of the healthcare professionals at the workplace may have a significant effect on their performance. The distractions may result in the slowing of the cognitive processes [2]. Even in a low sound level array, acoustic interferences can affect the employees' efficiency, work capacity, and attentiveness [3]. When the difference between the speech level and the sound level of the interfering noise exceeds 15 dB(A), it reduces speech intelligibility. 50 dB(A) is considered the sound pressure level of normal speech, so when the interfering noise level exceeds 35 dB(A), it reduces speech intelligibility [4]. In its guideline for community noise, the World Health Organization recommended that the average background noise in medical settings where patients are treated or observed should not exceed 35 dB(A) [4]. The United States Environmental Protection Agency recommended values of 45 dB(A) during the day and 35 dB(A) at night at the patient observation areas [5]. The state of happiness and well-being greatly influences healthcare workers' attitudes towards their patients, their ability to interact with patients, disseminate information, and provide quality medical care [6]. Elevated noise interferes with the communication between the healthcare staff and the patients and affects complex tasks during patient observation and treatment. It also tends to increase work-related stress among healthcare professionals resulting in fatigue and irritation at the workplace. Strategies for improving the work conditions of the healthcare workers are of utmost importance for reducing burnout at work which, in turn, will enhance the well-being of the healthcare workers [6].

Overcrowding of patients and their demands add up to the work stress for the healthcare workers. A previous study revealed that overcrowding of patients at the health camps sometimes causes conflicts between patients and physicians [7] and affects the overall cognitive performance of healthcare professionals. The effect of overcrowding on mental health correlates with the high workload [8] of the physicians. Interruptions during task performance are often linked to errors in outcomes, inefficiency and adversely affect the healthcare service delivery by causing delays and interfering in providing effective healthcare [9].

An investigative study on the cognitive load and its contributing factors among healthcare professionals provide valuable information on minimizing its impact on their performance. Developing tactics for easing work-related stress of the healthcare

staff is crucial as work stress may escalate cognitive load among the healthcare professionals, thus risking patients' safety [10]. Evaluating the contributing factors that escalate cognitive load among healthcare professionals is invaluable before entering the prevention domain. Assessing the stressors associated with cognitive load helps develop strategies for minimizing its impact on healthcare professionals.

The current research investigates how overcrowding and acoustic distractions escalate cognitive load among healthcare professionals. The study considers the individual cognitive performance of healthcare professionals due to acoustic distraction and congestion of patients. It does not consider the joint tasks performed at the health camps.

2 Research Methodology

The study involved participants who were direct stakeholders of the health camp journey. Field study was carried out in seven (07) different health campsites of rural Assam. We conducted a walkthrough survey in each of the health campsites for accumulating information on the health camp environment, such as its location, any construction work in progress, proximity to main roads, agricultural lands, marketplace, etc., and other prevalent external noise sources in and around the health camps. The perspectives of Thirty-seven (37) healthcare professionals belonging to different fields (medicine, ophthalmology, gynecology, optometry, nurse, pediatrics) were captured through interviews and a specially crafted questionnaire. During the interview, the healthcare professionals responded to questions aimed at extracting information on the camp experience, camp setting (open area or closed room), health camp process, duration of camp, how the camp setting is different from the clinical setting, etc.

At the end of each health camp, the healthcare professionals were handed a questionnaire in a sealed envelope. We provided a timeframe of 7 days for completing the questionnaire and then collected it from the respective healthcare professionals. Before distributing the questionnaire for the actual project, the validity and reliability of the questionnaire were inspected by distributing the questionnaire to a team of healthcare experts having experience in health camps. After consultation, we made some modifications to the questionnaire and used it in our actual study. The questionnaire is divided into three sections. The first section collects the demographic details of the respondents (age, sex, marital status, a habit of smoking/drinking, etc.). The second and third sections of the questionnaire had questions regarding the impact of acoustic distraction (background noise) and overcrowding on the cognitive performance of healthcare professionals. The questions were designed to collect the insights of different healthcare professionals (medicine, ophthalmologist, gynecologist, optometrist, nurse, and pediatrician) on the effect of acoustic distraction and overcrowding at the health campsites. The questionnaire helped identify the main factors contributing to noise levels during the health camps at the rural sites

and provided us with insights regarding the impact of acoustic interferences and overcrowding on the health professionals during the health camp.

The questionnaires were filled by 37 healthcare professionals (a 100% response rate) from different healthcare fields. Table 1 provides the detailed demographics of the healthcare professionals completing the questionnaire survey, and Table 2 offers the responses to the questionnaire questions by the healthcare professionals. Different factors affecting the cognitive performance of the health care experts due to acoustic distraction and overcrowding at the health camps (obtained from the questionnaire) are analyzed using a radar plot.

3 Results and Discussion

3.1 Setting and Sample Description

The study was conducted in 7 different rural health campsites in the state of Assam. It involved 37 (thirty-seven) healthcare experts belonging to different fields of their profession. 16% of the respondents had a background in medicine, 14% in ophthalmology, 19% were gynecologist, 11% of the sample were optometrist, 27% were working as a nurse, and 13% were pediatrician (Table 1). 70% of the sample were married, 32% considered smoking, and 43% had a habit of drinking. The study population's range of health camp experience was from 3 to 21 years (Mean $\pm$ SD $=$ 9.4 $\pm$ 5.2 in years). The response rate of the study was a complete 100%.

3.2 Responses of the Healthcare Professionals Concerning Noise and Overcrowding at the Health Camps

Responses to the questions concerning the prevalence of noise and overcrowding at the health camp settings are provided in Table 2. From the answers, it is evident that noise and overcrowding play a significant role in adding to cognitive load among healthcare professionals in a health camp environment. The healthcare professionals (57%) reported that working in a health camp is uncomfortable due to the noise interferences, and about 46% said that overcrowding is responsible for an uncomfortable work environment (Table 2). Visitor conversation (73%) was considered to be the most contributing factor of noise in a health camp setting, followed by sound from agricultural machines (35%) in close proximity to the health campsites and ongoing construction work (30%). The healthcare professionals projected the lack of a patient management system (66%) followed by patient behavior (51%) to be the leading factor of overcrowding/congestion of patients at the health camps (Table 2).

From Table 2, the time frame between 12:00 p.m. to 2:00 p.m. seems crucial as 59% of the respondents mentioned that the health camp environment is the noisiest,

Table 1 Demographic profile of the respondents (N = 37)

	Categories of healthcare professionals						Total
	Medicine	Ophthalmologist	Gynecologist	Optometrist	Nurse	Pediatrician	
Sample size N (%)	6 (16)	5 (14)	7 (19)	4 (11)	10 (27)	5 (13)	37 (100)
Variables							
Sex							
Male	5	3	4	2	0	3	17 (46)
Female	1	2	3	2	10	2	20 (54)
Age in years							
20–39	2	1	1	4	7	2	17 (46)
40–59	4	2	5	0	3	3	17 (46)
≥60	0	2	1	0	0	0	3 (8)
Married (%)	5 (83)	4 (80)	7 (100)	0	6 (60)	4 (80)	26 (70)
Unmarried (%)	1 (17)	1 (20)	0	4 (100)	4 (40)	1 (20)	11 (30)
Smoking (%)	3 (50)	3 (60)	2 (29)	1 (25)	1 (10)	2 (40)	12 (32)
Drinking (%)	3 (50)	2 (40)	3 (43)	2 (50)	3 (30)	3 (60)	16 (43)
Years of health camp experience [Mean(SD)]	10.8 (4.4)	13.4 (5.2)	12.8 (4.8)	4.25 (0.8)	6.5 (3.7)	8.6 (4.3)	9.4 (5.2)

Table 2 Responses of the respondents (N = 37)

Noise			Overcrowding/congestion		
Questions	Answers	Total N (%)	Questions	Answers	Total N (%)
How will you rate the work environment in the health camp setting	Extremely Uncomfortable	7 (19)	How will you rate the work environment in the health camp setting	Extremely Uncomfortable	12 (32)
	Uncomfortable	21 (57)		Uncomfortable	17 (46)
	Neutral	6 (16)		Neutral	8 (22)
	Comfortable	3 (8)		Comfortable	0
	Extremely comfortable	0		Extremely comfortable	0
What are the different noise sources you encounter in a health camp setting	Medical equipment	0	What, according to you, are the factors that lead to overcrowding at the health camps	Lack of patient management system	25 (66)
	Visitor conversations	27 (73)		Patient behavior	19 (51)
	Construction work	11 (30)		Demand	14 (38)
	Babies crying/Kids playing	9 (24)		Wrong referral	9 (24)
	Ringing phone	4 (11)			
	Agricultural machines	13 (35)			
	Traffic	7 (19)			
	Others	4 (11)			
Which time frame do you consider the noisiest in the health camps	8:00–10:00	2 (5)	Overcrowding/congestion of patients is witnessed around	8:00–10:00	5 (13)
	10:00–12:00	5 (13)		10:00–12:00	9 (24)
	12:00–2:00	22 (59)		12:00–2:00	18 (49)
	2:00–4:00	8 (22)		2:00–4:00	5 (13)
	4:00–6:00	0		4:00–6:00	0
In what way does the presence of noise affect you during the health camp	Effective Communication	28 (76)	In what way does congestion of patients affect you during the health camp	Effective Communication	24 (65)
	Speech Intelligibility	28 (76)		Speech Intelligibility	28 (76)

(continued)

Table 2 (continued)

Noise			Overcrowding/congestion		
Questions	Answers	Total N (%)	Questions	Answers	Total N (%)
	Concentration Level	29 (78)		Concentration Level	34 (92)
	Medical Error	15 (41)		Medical Error	27 (73)
	Performance of complex task	22 (59)		Performance of complex task	26 (70)
	Processing information	29 (78)		Processing information	27 (73)
	Functional Memory	21 (57)		Functional Memory	21 (57)
	Stress	27 (73)		Stress	30 (81)
	Fatigue	15 (41)		Fatigue	25 (68)

and 49% also reported experiencing congestion of patients during this period. The effects of noise and congestion of patients on different health care professionals are discussed in detail in the following sections (Tables 3 and 4).

3.3 Impact of Acoustic Distraction at the Health Camps

The healthcare experts revealed in their responses how background noise and other forms of auditory distractions affect their cognitive performance and increase their cognitive load. Table 3 lists the various factors affecting the healthcare experts while working at the rural health camps due to acoustic distraction. They are categorized as effective communication, speech intelligibility, concentration level, medical error, performance of complex task, processing information, functional memory, stress, and fatigue.

A total of 83% of the doctors of medicine reported that background noise and other sources of acoustic distraction contribute to ineffective communication between patients and other staff members. 83% reported experiencing reduced speech intelligibility and degrading capability in information processing. 67% informed that they could not concentrate on their tasks appropriately, and acoustic distraction lowers their functional memory capacity and causes stress among them. Half of the doctors having background of medicine mentioned that noise somehow affects their performance while performing complex tasks. 33% reported encountering medical errors due to the distractions caused and also mentioned of experiencing fatigue.

Table 3 Factors affecting healthcare experts due to acoustic distraction at health camps

Factors	Healthcare professionals						Total
	Medicine	Ophthal-mologist	Gynecologist	Optom-etrist	Nurse	Pediatrician	
Effective communication	5 (83)	3 (60)	5 (71)	3 (75)	8 (80)	4 (80)	28 (76)
Speech intelligibility	5 (83)	5 (100)	4 (57)	4 (100)	6 (60)	4 (80)	28 (76)
Concentration level	4 (67)	4 (80)	5 (71)	4 (100)	7 (70)	5 (100)	29 (78)
Medical error	2 (33)	3 (60)	1 (14)	2 (50)	4 (40)	3 (60)	15 (41)
Performance of complex task	3 (50)	2 (40)	4 (57)	3 (75)	6 (60)	4 (80)	22 (59)
Processing information	5 (83)	3 (60)	5 (71)	3 (75)	9 (90)	4 (80)	29 (78)
Functional memory	4 (67)	2 (40)	3 (43)	2 (50)	6 (60)	4 (80)	21 (57)
Stress	4 (67)	4 (80)	5 (71)	3 (75)	8 (80)	3 (60)	27 (73)
Fatigue	2 (33)	2 (40)	3 (43)	2 (50)	4 (40)	2 (40)	15 (41)

Among the ophthalmologists, 60% reported of suffering from ineffective communication, encountering medical error, and problem in processing of information. All of the ophthalmologists reported reduced speech intelligibility due to acoustic distraction. 80% mentioned that acoustic distraction affects their ability to concentrate at task and increases stress among them. 40% of them complained of facing problems in performing complex tasks, reduced functional memory capability, and experiencing fatigue.

71% of the gynecologists reported suffering from ineffective communication, lowering of concentration level, problem in processing information, and increased stress level. 57% complained of reduced speech intelligibility and difficulty in performing complex task as a result of acoustic distraction. 43% reported of lowering in their functional memory capability and experiencing fatigue. Only 14% reported of encountering medical errors due to noise distraction at the health camps.

Around 75% of the optometrists complained of ineffective communication, difficulty in performing complex task and processing information, and an increased level of stress. All the optometrists complained of reducing speech intelligibility and concentration level due to acoustic distraction. Half of the optometrists (Table 3) reported of encountering medical error, lowering in functional memory capability, and experiencing fatigue.

Of the nurses, 80% reported of experiencing ineffective communication and stress. 60% of the nurses mentioned that there is a reduction in speech intelligibility, difficulty in performing complex task, and lowering of functional memory capability due to acoustic distraction at the health camps. 70% of them reported of a lowering of concentration level during work. 40% of the nurses mentioned encountering medical error and fatigue as a result of these distractions caused by sound. A 90% (Table 3) of the nurses complained of having problems in processing information at the health camps due to the prevalence of acoustic distractions.

80% of the pediatricians of the health camps also complained of ineffective communication, reducing speech intelligibility, difficulty in performing complex task and information processing, and a lowering of functional memory. All of them complained of a reduction of concentration level at their tasks due to acoustic distraction. 60% reported of encountering medical error and increased levels of stress. A 40% of them mentioned experiencing fatigue (Table 3).

From Table 3, it is clear that the prevalence of acoustic distraction at the health camps has an adverse effect on the factors- effective communication, speech intelligibility, concentration level, processing information, and stress. It moderately affects factors like- performance of complex task, and functional memory and mildly affects medical error and fatigue. Though medical error as a result of acoustic distraction is affected mildly (41%) (Table 3), even a single case of medical error may result in poor patient outcome and hence cannot be ignored.

3.4 Impact of Overcrowding at the Health Camps

A total of 67% of the doctors of medicine reported that overcrowding of the patients at the health camps contributes to ineffective communication between patients and other staff members, results in medical errors, degrading capability in information processing, difficulty in performing complex task, lowering of functional memory and experience of fatigue. 83% (Table 4) informed of experiencing a reduction in speech intelligibility, lowering of concentration level, and increased stress.

Among the ophthalmologists, 60% reported suffering from ineffective communication and lowering of functional memory. All of the ophthalmologists reported reduced speech intelligibility and concentration level due to overcrowding. 80% (Table 4) mentioned that overcrowding results in medical error, affect in the performance of complex task and information processing and increases stress levels and causes fatigue.

71% of the gynecologists reported suffering from ineffective communication, medical error, and experiencing fatigue. 57% reported reduced speech intelligibility, difficulty in processing information, and lowering of functional memory capacity. 86% of the gynecologists had a problem with concentration level, difficulty in performing complex task, and increased stress level.

Around 75% of the optometrists complained of ineffective communication, medical error, difficulty in performing complex tasks and processing information, and an increased level of stress and experiencing fatigue. All the optometrists complained of reducing speech intelligibility and concentration level due to overcrowding. Half of the optometrists (Table 4) reported experiencing a lowering in functional memory capability.

Of the nurses, 60% reported experiencing ineffective communication, reduced speech intelligibility, and fatigue. 80% of the nurses mentioned that they find difficulty in processing information and experience stress at work. 90% of them reported a lowering of concentration level during work, and 70% of the nurses mentioned encountering medical errors as a result of overcrowding. Half of the nurses also reported facing difficulty in performing complex task and lowering of functional memory due to overcrowding (Table 4).

80% of the pediatricians of the health camps also complained of reducing speech intelligibility, difficulty in performing complex task and information processing, encountering medical errors, and increased stress levels. All of them complained of a reduction of concentration level at their tasks due to overcrowding. 60% complained of ineffective communication, lowering of functional memory, and experiencing fatigue (Table 4).

From Table 4, it is clear that overcrowding of the patients at the health camps have an adverse effect on the factors-, speech intelligibility, concentration level, medical error, performance of complex task, processing information, and stress. It moderately affects factors like- ineffective communication, functional memory, and experience of fatigue. Table 4 clearly indicates that the concentration level (92%) among the healthcare professionals is most adversely affected due to overcrowding.

Table 4 Factors affecting healthcare experts due to overcrowding at health camps

Factors	Healthcare professionals						Total
	Medicine	Ophthal-mologist	Gynecologist	Optom-etrist	Nurse	Pediatrician	
Effective communication	4 (67)	3 (60)	5 (71)	3 (75)	6 (60)	3 (60)	24 (65)
Speech intelligibility	5 (83)	5 (100)	4 (57)	4 (100)	6 (60)	4 (80)	28 (76)
Concentration level	5 (83)	5 (100)	6 (86)	4 (100)	9 (90)	5 (100)	34 (92)
Medical error	4 (67)	4 (80)	5 (71)	3 (75)	7 (70)	4 (80)	27 (73)
Performance of complex task	4 (67)	4 (80)	6 (86)	3 (75)	5 (50)	4 (80)	26 (70)
Processing information	4 (67)	4 (80)	4 (57)	3 (75)	8 (80)	4 (80)	27 (73)
Functional memory	4 (67)	3 (60)	4 (57)	2 (50)	5 (50)	3 (60)	21 (57)
Stress	5 (83)	4 (80)	6 (86)	3 (75)	8 (80)	4 (80)	30 (81)
Fatigue	4 (67)	4 (80)	5 (71)	3 (75)	6 (60)	3 (60)	25 (68)

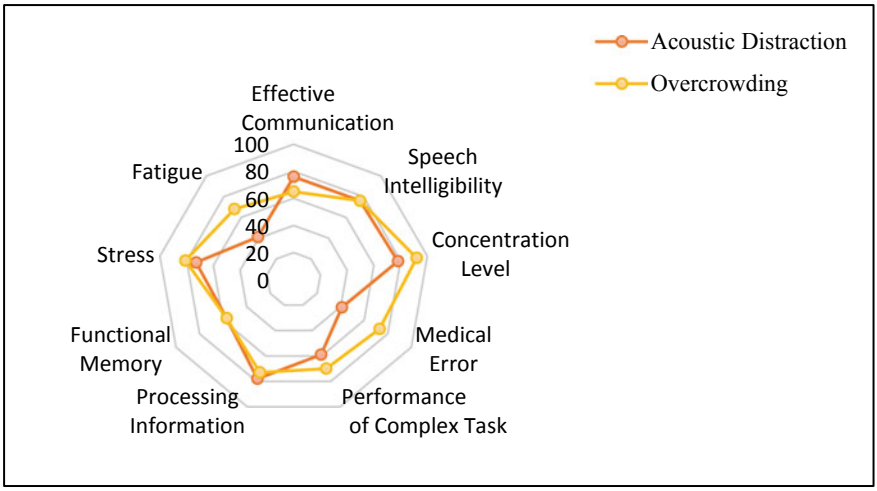

Fig. 1 Comparative analysis of the factors affecting healthcare experts as a result of acoustic distraction and overcrowding at health camps

3.5 Comparative Analysis of the Factors Affecting Cognitive Performance

A comparative analysis of the different factors affecting the cognitive performance of the health care experts due to the presence of acoustic distraction and overcrowding at the health camps is made using a radar plot (see Fig. 1). It is clear that the effect on effective communication, processing information due to acoustic distraction at the health camps is more prevalent than that as a result of overcrowding. On the other hand factors like concentration level, medical error, the performance of complex task, stress, and fatigue due to overcrowding at the health camps is more prominent than that due to acoustic distraction. Speech intelligibility and functional memory share the same impact level due to acoustic distraction and overcrowding (see Fig. 1).

4 Conclusion

In conclusion, the research justified that due to the presence of acoustic distraction and overcrowding of the patients at the health camps, the healthcare professionals have to undergo several challenges that affect their cognitive performance and escalates cognitive load. The results provide insight into how acoustic distraction and overcrowding at the health campsites act as barriers to imparting safe and high-quality healthcare.

The prevalence of acoustic distraction at the health camps has an adverse effect on effective communication, speech intelligibility, concentration level, processing

information, and stress. It moderately affects the performance of complex task, and functional memory and mildly affects medical error and fatigue. Overcrowding of the patients at the health camps have an adverse effect on speech intelligibility, concentration level, medical error, the performance of complex task, processing information, and stress. It moderately affects ineffective communication, functional memory, and experience of fatigue.

Interventions like having a proper patient management system for controlling the patient inflow at the health camps, using soundproofing foam at the health camp setting for masking background noise have been proposed. As the current research has a limited sample size, future research should be conducted with a larger sample size for gaining deep understandings of the effect of noise and overcrowding on the cognitive state of healthcare professionals. Analysis of the effect of auditory distraction based on age, sex of the healthcare professionals can also prove beneficial. Future work also suggests performing the Montreal Cognitive Assessment (MoCA) test to analyze the healthcare professionals' cognitive state before and after attending health camps. Investigating the effect of noise intensity on the cognitive load of healthcare professionals will also come in handy in future research. By performing this, we can adequately understand the impact of noise and overcrowding on the healthcare professionals' cognitive load at health camps.

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Impact of Select Design Characteristics in Food Packaging on Consumer Behavior: A Study on Elderly Population in Kolkata

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Abstract Nutritional label is one of the strategies to assist the public in making healthier food choice. Although an important aspect of food packaging, nutrition labeling is often overlooked; it is all the more important for elderly population where visibility and cognitive functions start to decline. In this backdrop, an attempt has been made to assess the impact of select design characteristics of food packaging on purchasing behavior of elderly population in Kolkata. Nutritional label for geriatric health drink was selected for the present study. 39 consenting individuals, (male n = 18 and female n = 21) within the age range of 60–75 years participated in the study. General physical and cognitive health status were assessed. Information related to preferences for packaging material, container, graphics, font and color were collected. Findings of the present work revealed that the study participants have specific preferences regarding packaging type and design. They preferred bottles, glass as packaging material, simple graphics, large font size and subdued colors. It was also found that they most frequently look for the product's best before use date, its manufacturer's name and product composition. Based on their preference, prototype for placing of relevant information on the product was designed and the response regarding noticeability, readability and likelihood of behavior change of the consumers was collected. It may be concluded that for a more inclusive purpose, continuous improvement in packaging design is important which will address the challenges for older people.

Keywords Consumer preference · Geriatric population · Inclusive design · Packaging material · Purchasing decisions · Nutritional labeling

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1 Introduction

Food packaging helps to contain the food in a cost-effective way, to protect food products from external influences and damage, and to provide consumers with ingredient and nutritional information. In addition to these, it also helps in traceability, convenience, and indicating tamper. All these functions help in maintaining food safety and minimizing environmental impacts [1]. In food packaging, a nutritional label, which is a list of nutrient level of a product displayed on the food label, is one of the most frequently studied attributes. The purpose of nutritional label is to provide the salient facts about the nutrition contents of the product. It is one of the population-level intervention strategies for communicating nutrition information to assist the common people in making healthier food choice [2]. When designing the labels for food products, manufacturers need to follow certain legislative guidelines directed by the government of a particular country, in addition to providing detailed and exact nature and characteristics of the food product without misleading the consumers. Although an important aspect of food packaging, nutrition labeling is often overlooked; it is all the more important for elderly population (60 years and above), a section of population which continues to grow at an unprecedented rate and where complex physiological changes occur in body and mind resulting into exposure with numerous challenges [3]. Therefore, considering elderly persons as a target group of consumer as well as purchaser of a packaged food is a challenge and if their needs are fulfilled, it can contribute to the development of products as well as the quality of life of the said population. In spite of the importance, only a handful of studies have focused on particular design characteristics of food packaging especially meant for elderly population. In this backdrop, an attempt has been made to assess the impact of select design characteristics of food packaging on purchasing behavior of elderly population in Kolkata.

2 Methodology

The study was conducted on 39 consenting individuals, (male n = 18 and female n = 21) within the age range of 60–75 years residing in and around Kolkata metropolitan area. The information on consumer's socio-demographic characteristics (age, marital status, smoking and drinking status), general health status (known history of hypertension, diabetes and arthritis), cognitive health status (using Mini Mental State Examination), purchasing behavior (location of purchasing food products), and use and understanding of the food labels on geriatric health drink were collected. The ability and the time needed to find the relevant information were studied. Information related to preferences for packaging container material, graphics, font and color were collected. Study participants were asked to give their preference regarding different

label design characteristics [4] namely border versus no border, presence of background versus no background, background color and preference of the product 'with caution' symbol versus 'without caution' symbol.

3 Results

The study participants (39) were Hindu Bengalee retired pensioners. All of the participants were graduates and above, none of them were illiterates and none of the participants had cognitive impairments. The participants themselves were the major purchaser of the groceries to the family. Distribution of socio-demographic characteristics, lifestyle and physical health status are presented in Table 1.

Figure 1 represents consumer response regarding frequency of examining the nutrition label information, one of the fundamental aspects during purchasing packaged food items.

Table 1 Distribution of respondents according to the socio-demographic characteristics, lifestyle and physical health status

Variables	Percentage
Sex	
Male	46.2
Female	53.8
Marital status	
Married	35.9
Widow/widower	64.1
Smoking status	
Non-smoker	67.1
Smoker	19.7
Ex-smoker	13.1
Alcohol consumption	
No	95.5
Occasionally	4.5
Known hypertension	
Yes	39.9
No	60.1
Known diabetes	
Yes	28.2
No	71.8
Arthritis	
Yes	5.1
No	94.1

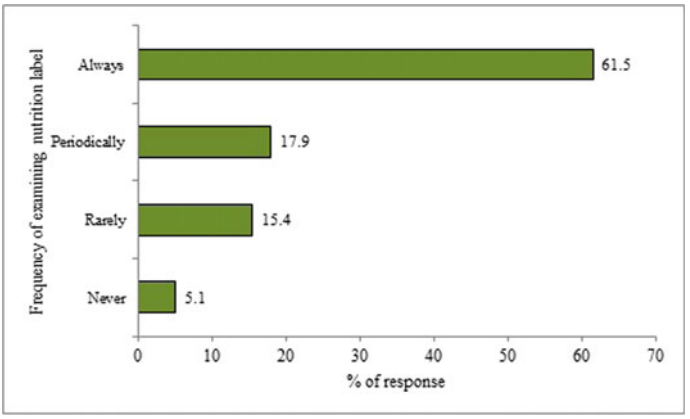

Fig. 1 Consumer response regarding frequency of examining the nutrition label information

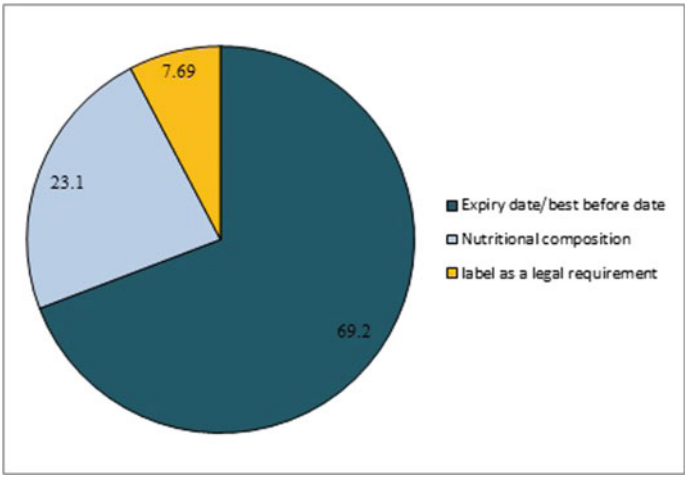

Fig. 2 Consumer response (%) regarding their perception about requirement of label

From Fig. 1 it is observed that consumer awareness of the present study population regarding examining nutrition label is quite high. 61.5% of the study participants always examine nutrition label while the concerning matter is that 5.1% study population do not examine nutrition label any time.

Consumer perception about requirement of label is another important factor to consider. Figure 2 depicts consumer response (%) regarding their perception about requirement of label.

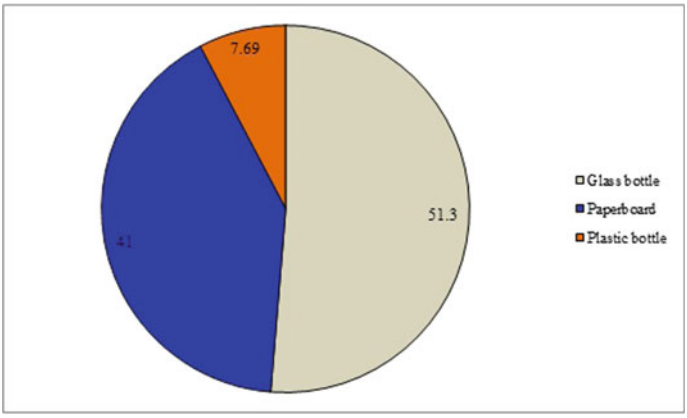

Fig. 3 Consumer response regarding their preference for packaging material

It is found that 69.2% study population thinks nutrition label requirement is only for finding expiry date or best before date, while 23.1% emphasizes on finding nutritional composition and 7.69% consider nutritional labeling as legal compulsion.

Figure 3 presents consumer preference regarding packaging container material, a factor with potential to influence purchase decision.

It has been found that the study participants prefer glass jar as a packaging container material in spite of the heaviness of the item.

Consumer responses regarding impact of select characteristics of packaging and labeling, namely packaging color, label on package, type of labeling and orientation of nutritional information (horizontal or vertical) on purchase decision is presented in Fig. 4.

It is observed that labeling color is a strong determinant of product purchasing. Majority of individuals prefer proper labeling on packaged product. Moreover, interpretive FOP labeling system is preferred choice and most of the consumer accepts horizontal orientation of nutrition labeling.

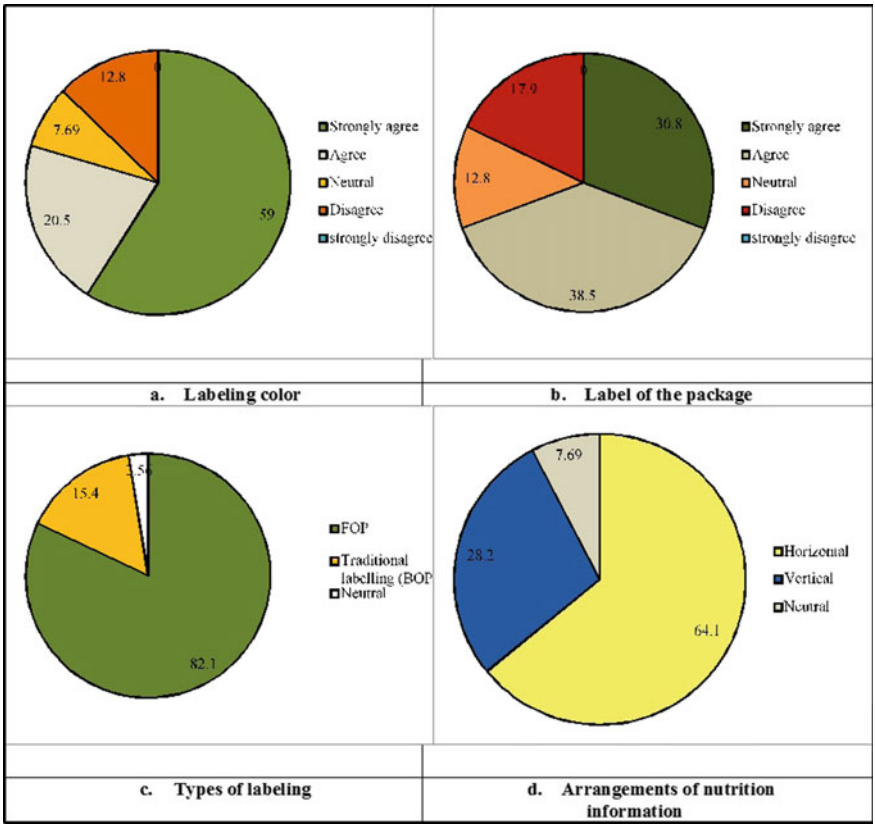

Fig. 4 Consumer response regarding impact of select characteristics of packaging and labeling on purchase decision

Figure 5 shows consumer responses regarding their preferences about select label design characteristics like border around nutrition label, presence of background along with background color and presence of caution symbol.

From Fig. 5, it can be observed that the respondents preferred the label 'with a border' as more noticeable than a label with 'no border', they also prefer presence of background (yellow) in label and a label with caution symbol.

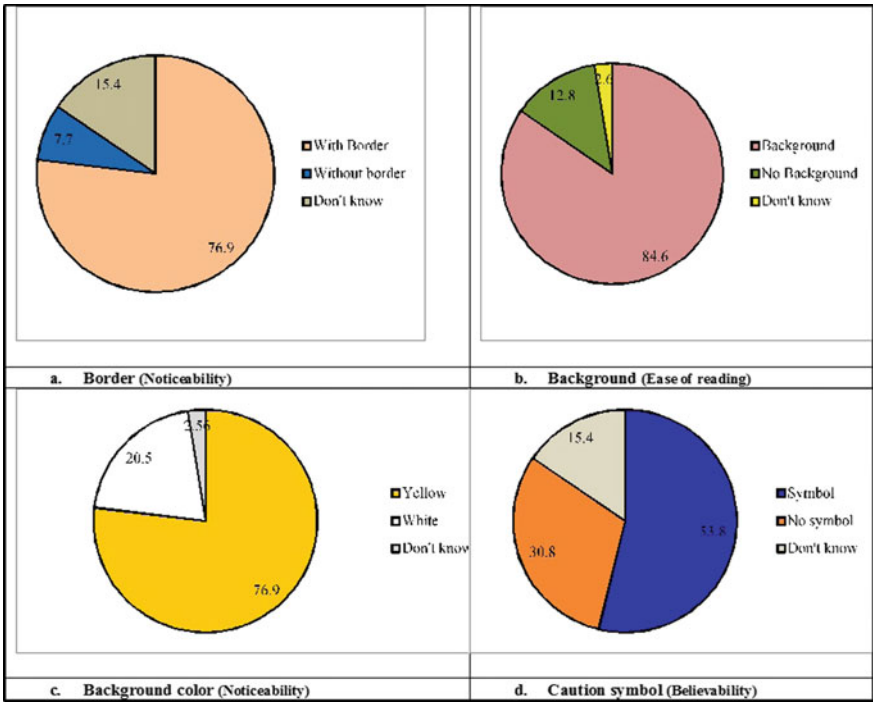

Fig. 5 Consumer responses regarding their preferences about label design characteristics

Figure 6 shows the percentage of consumer response regarding best caution symbol which they would like to see in FOP.

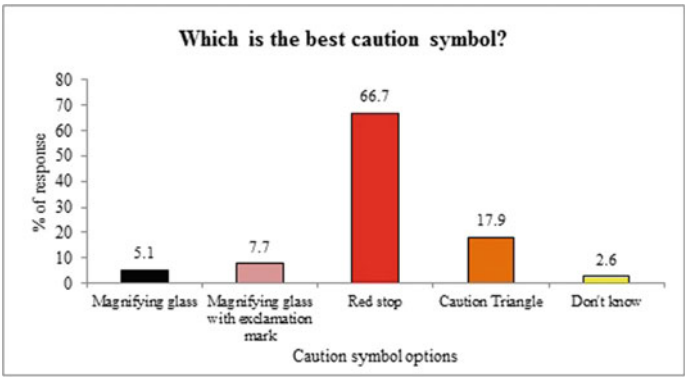

Fig. 6 Consumer perception response regarding the 'best caution symbol'

From Fig. 6, it is observed that 'Red stop' is the most preferred caution symbol followed by caution triangle, magnifying glass with exclamation mark and only magnifying glass symbol.

4 Discussion

Balanced diet along with regular physical exercise is a key for a healthy life [5]. Due to globalization and urbanization, consumption of packaged food products has been increased a lot. Accurate and easy-to-understand nutrition labeling is an important public health goal [6]. Nutrition labeling plays a pivotal role in providing all the mandatory information regarding nutritional composition, safe and quality food, which need to be available to the consumers. Studies have reported that nutrition label has played significant role in developing healthier food choice [7] and thus can prevent various diseases linked with unhealthy dietary intake including obesity [6] and its associated consequences, high prevalence [8–11] of which is a real concern for a country like India despite adoption of various intervention strategies [12–42].

There is a dearth of research study especially in Indian context which focuses on impact of design characteristics of food packaging on purchasing behavior of elderly individuals. In this regard present study was designed focusing on Bengalee elderly population. The findings indicated that the consumers have clear preferences for several design attributes of health drink products. In the present study, 61.5% of study population responded as they always examine label while purchasing a product. The major reasons for examining the food labels were whether it is a new product, to find any information regarding food allergies, to evaluate the suitability of the food product for vegetarians and like. Whereas, 5.1% study population do not examine nutrition label any time. The major reasons for not examining nutrition label were found to be lack of time and complex nature of food label which is in agreement with an earlier study [43]. In a food label, there are many things to examine like product name, brand name, nutritional value, country of origin, method of opening the container, storage condition, preparation/use method and like but in the present study, 69.2% study population thinks nutrition label requirement is only for finding expiry date or best before date (although they take long time to find the expiry date on the label), while 23.1% emphasizes on finding nutritional composition and 7.69% consider nutritional labeling as legal compulsion only. Present study is in agreement with earlier studies where it was found that the most frequent search information of a label was expiration date/best before date [44]. There are a variety of packaging materials that are commonly used. In the present work, in spite of the heaviness, glass bottle was preferred by the respondents compared to paperboard and plastic bottle. There is a growing concern regarding environmental sustainability of packaging material as it contribute to a great extent as waste material [45]. In this regard, consumer perception is eco-friendly. Color of nutrition label of a packaged product is one of the most characteristic features. In the present study, 59% of study participants strongly agreed with the fact that the nutritional labeling color is a strong determinant

of product purchasing which is similar to an earlier finding [46]. Another good indication of consumer awareness among the participants is that majority of individuals prefer proper labeling on packaged product. In the present study, consumers reported to have difficulty in reading and understanding nutrition facts panel sometimes and hence they would prefer the FOP labels. A growing body of researchers have found that FOP labels, which present truncated nutrition information on the front of the package in varied forms, is an effective strategy for enhancing consumer attention due to its simplified format and prominent position compared to the traditional labeling (those on the backs of package (BOP) [47]. The Food Safety Standards Authority of India (FSSAI) is presently considering implementing symbol-based front-of-pack nutrition labeling. Sometimes nutrition information and allied things are presented on FOP type in vertical or horizontal orientations and in this regard, present study populations prefer horizontal orientation. Nutritional information on the label can be presented in various ways. In the present work respondents rated the label 'with a border' as more noticeable than a label with 'no border', they prefer presence of background than 'no background' and yellow as the preferred background color in label. Further study participants reported that they prefer a product with caution symbol; all these characteristics of labeling influence their purchasing behavior. On obtaining the information that the consumers prefer a product with caution symbol, a variety of caution symbols were presented to them and they prefer 'red stop' symbol is the most easily understandable caution symbol; present finding is in tune with an earlier study [48]. In addition to these, few suggestions were obtained from the study participants that they want to incorporate in the label like bigger font, easy, simple and specific information and attractive label. The study has been conducted to give an initial idea about packaging and labeling design characteristics of products which may influence the purchasing decision of the consumer, but because of the small sample size for being a sort of a pilot study, it has a limitation as well. As the design of product labeling is a dynamic area, the study findings may be useful in further improvement of product design for better acceptance of the product.

5 Conclusion

From the present study it may be concluded that the elderly consumers have specific preferences regarding food packaging including nutritional labeling. They prefer FOP labeling, glass as packaging material, simple and specific graphics, logos, larger font, specific background packaging colors and specific warning symbol. Inclusive design in product packaging including labeling aspect needs to be considered as a priority area in the fast changing global market.

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Influence of Yoga Practice on Body Composition and Cardio-Respiratory Functions of Adolescent Male

Indranil Manna

Abstract Yoga has beneficial effects on physical fitness and health of children and adolescent. This study was designed to observe the influence yoga practice on body composition and cardio-respiratory functions of adolescent male volunteers. A total of 168 male volunteers (age: 16–18 years) were randomly selected, and 68 were excluded, the remaining 100 were divided into (a) yoga practice group ($n = 50$) and (b) sedentary control group ($n = 50$). A yoga training protocol of 60 min/d, 6 d/week for 12 weeks was followed by the subjects of yoga practice group, where as no such training was given in sedentary control group. Measurement of body composition and cardio-respiratory variables were performed in both the groups at 0-week and 12-weeks. A reduction ($P < 0.05$) in body fat percentage, systolic blood pressure (SBP), diastolic blood pressure (DBP), resting heart rate (RHR) and respiratory rate (RR); and elevation ($P < 0.05$) in forced expiratory volume in 1st sec (FEV1), forced vital capacity (FVC), peak expiratory flow rate (PEFR), maximum ventilatory volume (MVV), and breath holding time (BHT) were observed among yoga practice group after 12 weeks. Reduced ($P < 0.05$) body fat, blood pressure, heart rate and respiratory rate; and improved ($P < 0.05$) level of FVC, FEV1, PEFR, MVV, and BHT were seen in the yoga practice group when compared to the sedentary control group after 12 weeks. It can be stated that regular yoga practice improves body composition and cardio-respiratory functions of adolescents.

Keywords Body composition · Blood pressure · Lung functions · Yoga

1 Introduction

Yoga originated in ancient India has various sub-types, and includes asana (posture-physical exercise), pranayama (breathing exercise) and meditation (focusing mind on a particular object), that is said to have positive impact on the body, mind and emotional well-beings. Yoga practice among the adolescent may improve health and

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mental status and thus increase the ability to adjust with stress in their daily life. Yoga practice generally performed by the way of physical exercises, and breathing exercises, and relaxation techniques [1]. A recent study suggested that yoga practice in the school may be an effective way to improve health of children and adolescents [2, 3]. It has been observed that yogic practice in schools may be useful to develop physical fitness, mood and self-regulation skills related to emotion and stress among the children and adolescents [4].

Yoga causes positive changes in physical and emotional wellbeing by using asanas and pranayama [1, 5]. Pranayama also influence different physiological systems. The recent research showed the beneficial effects of Pranayama in physiological studies and therapeutic practice. The therapeutic aspects of Pranayama on the neurological, cognitive, psychological and physiological functions were observed [1, 5]. Yoga and meditation provide the mind–body association. Meditation opens the door to self-actualization and makes union of mind–body-spirit [6]. The applications of yoga on children and adolescents reported improvement in physical and mental health [7, 8].

The adolescent period is one of the most important stages of human life, in which rapid changes in body composition and physiological and mental development take place. A balance between body composition and cardio-respiratory status is required to mention health and develop personality which helps to become a good citizen in future. Even in adolescent are engaged in long hour's study which includes reading and writing. Thus they may experience stress and strain which may reduce their performance. Practicing yoga can minimize injuries and health issues associated with of doing repeated tusk and bring comfort during work. The adolescents are the future work force of our country; it is optimum important to keep them mentally and physically fit. Yoga may be useful to keep up physical fitness and health this in turn may affect the performance of the adolescent. In view of this, the present investigation has been designed to find out the effects of short term yoga practice on body composition and cardio-respiratory functions of adolescent male volunteers.

2 Methods

2.1 Participants

For the present investigation one hundred sixty eight ($n = 168$) male adolescent volunteers (age 16–18 years) participated randomly from the Midnapore District, West Bengal, India. Subjects who have not participated in yoga for last one year were considered eligible for this study. Subjects were included having no recent history of disease and illness. This decision was taken by the Physicians based on the medical examination. Participants were excluded from the study if had a history of disease and illness at least 03 months prior to the study. The medical examination was conducted for all the participants. Sixty eight participants [$n = 68$ (not meeting the inclusion criteria, $n = 23$; decline to participate, $n = 12$; inability to perform

yoga, $n = 15$; and unable to follow the schedule, $n = 18$)] leave the study, and one hundred ($n = 100$) participants were grouped into: (a) Control participants ($n = 50$) and (b) Yoga participants ($n = 50$).

2.1.1 Human Study Ethics

The principles of ethical issues related human study were followed. The purpose of the investigation was explained and the consent was obtained. The yoga group participants were informed not to involve in any other physical activity during the entire period of intervention. The participants were asked to keep their traditional diet. The Institutional Ethical Committee (Human Studies) approved the investigation (Ref No. MC/IEC (HS)/PHY/FP-02/2016; date: 07.06.2016).

2.2 Experimental Design

The volunteers were acclimatized for 15 days prior to the intervention, where as the intervention was carried out for a period of twelve (12) weeks. Yoga training was provided to yoga participants for 60 min/day, 06 day/week for 12-weeks; with no such training in control participants. (Table 1) [9]. Body composition and cardio-respiratory functions were measured in all the participants at 0 week and at 12 weeks.

2.3 Measurements

2.3.1 Determination of Body Composition Variables

The height of the participants was taken using stadiometer (Seca 220, UK) [10]. The body mass of the participants was taken by weighing machine [10]. Body mass index (BMI) and Body surface area (BSA) were estimated [10]. Skin fold thickness was taken using skin fold calliper (Holtain Limited, UK) to assess the body fat percentage [11]; the body density was calculated [12]. Body fat, fat mass and lean body mass (LBM) were computed [11].

2.3.2 Measurement of Cardio-Respiratory Functions

Cardiovascular functions including resting heart rate (RHR) and blood pressure of the volunteers are measured in seating position after taking 15 min rest using the standard procedure [13]. The respiratory functions including the forced expiratory volume in 1st sec (FEV1), forced vital capacity (FVC), peak expiratory flow rate

Table 1 Protocol of yoga training

Protocol	Time (min)
Prayer	02
Om chanting	02
Gayatri Mantra	02
Yogic SukshmVyayam	10
Surya Namaskar	12
Yogasana	
(i) Shavasana	
(ii) Supt Pawan Muktasana	
(iii) Kandrasana	
(iv) Makarasana	
(v) Shalabhasana	10
(vi) Bhujangasana	
(vii) Mandukasana	
(viii) Usharasana	
(ix) Gomukhasana	
Pranayama	
(i) Kapal Bhati	
(ii) Mahabandh	15
(iii) Laybadh Shvas Prashwas	
(iv) Nadi Shodhan	
(v) Ujjayi and Bhramari Pranaya	05
Meditation	
(i) Ajpa Jap	02
(ii) Shanti Mantra	
Total	60

(PEFR), maximum ventilatory volume (MVV) were measured following a standard procedure using an electronic spirometer (Spirobank II, MIR, USA) [14]. Respiratory rate (RR) and breath holding time (BHT) was measured manually.

2.3.3 Statistical Analysis

A standard statistical software package SSPSS 20 for Windows (IBM, USA) was used for the statistical analysis. The Shapiro–Wilk normality test was conducted to check whether the data were normally distributed [15]. Descriptive statistics including the mean and standard deviation were computed [15]. The paired sample *t*-test was used to find out the differences among the within group and between group variables [16]. The difference was found significant when $P \leq 0.05$.

Table 2 Anthropometric variables of control participants and yoga participants

	Control participants		Yoga participants	
	0 Week	12 Weeks	0 Week	12 Weeks
Height (cm)	$164.7^{NS} \pm 4.6$	$164.7^{NS} \pm 4.6$	$165.1^{NS} \pm 5.1$	$165.1^{NS} \pm 5.1$
Body mass (kg)	$56.8^{NS} \pm 3.5$	$57.3^{NS} \pm 3.1$	$57.0^{NS} \pm 3.4$	$56.8^{NS} \pm 3.2$
BMI (kg m^{-2})	$20.8^{NS} \pm 1.6$	$21.1^{NS} \pm 1.5$	$20.9^{NS} \pm 1.63$	$20.4^{NS} \pm 1.58$
BSA (m^2)	$1.62^{NS} \pm 0.16$	$1.62^{NS} \pm 0.15$	$1.62^{NS} \pm 0.15$	$1.59^{NS} \pm 0.14$
Body fat (%)	$15.2^{NS} \pm 2.8$	15.0 ± 2.5	14.7 ± 2.6	$12.2^{*\#} \pm 2.7$
Fat mass (kg)	8.6^{NS} 3 ± 1.8	$8.60^{NS} \pm 1.7$	$8.39^{NS} \pm 1.7$	$7.9^{NS} \pm 1.6$
LBM (kg)	$48.2^{NS} \pm 4.6$	$48.7^{NS} \pm 4.4$	$48.7^{NS} \pm 4.5$	$47.6^{NS} \pm 4.1$

[mean ± SD; $n = 50$; compared to 0 week $^*P < 0.05$; compared to control participants # $P < 0.05$]

3 Results

3.1 Influence of Yogic Asana on Body Composition

A significant reduction ($P < 0.05$) in percentage body was noted in yoga participants at the end of the investigation (12 weeks) when compared to 0 wk. Yoga participants also showed significantly lower body fat than control participants at the end of the investigation (12 weeks). No change in body mass, BMI, BSA, and LBM was noted in yoga participants at the end of the study (12 weeks). No distinct change in body composition variables was observed among the control participants at the end of the investigation (12 weeks) [Table 2].

3.2 Influence of Yogic Asana on the Cardio-Respiratory Functions

A reduction ($P < 0.05$) in systolic blood pressure (SBP), diastolic blood pressure (DBP) and RHR was reported in yoga participants at the end of the investigation (12 weeks) when compared to 0 wk. Further, reduced ($P < 0.05$) SBP, DBP and RHR was observed in the yoga participants compared to the control participants at the end of the investigation (12 weeks). No change in SBP, DBP, and RHR was reported in the control participants at the end of the investigation (12 weeks) [Table 3].

Table 3 Cardiovascular response of control participants and yoga participants

	Control participants		Yoga participants	
	0 Week	12 Weeks	0 Week	12 Weeks
SBP (mmHg)	$122.3^{NS} \pm 5.1$	122.1 ± 5.2	$122.1^{NS} \pm 4.6$	$118.2^{*\#} \pm 4.1$
DBP (mmHg)	$79.7^{NS} \pm 4.7$	80.1 ± 4.4	79.8 ± 3.2	$77.2^{*\#} \pm 3.6$
Resting HR (beats/min)	$83.9^{NS} \pm 4.0$	$83.2^{NS} \pm 4.3$	$84.5^{S} \pm 4.1$	$79.2^{*\#} \pm 4.3$

[mean ± SD; $n = 50$; compared to 0 week $^*P < 0.05$; compared to control participants # $P < 0.05$]

Table 4 Pulmonary functions of control participants and yoga participants

	Control participants		Yoga participants	
	0 Week	12 Weeks	0 Week	12 Weeks
FVC (L)	$3.1^{NS} \pm 0.61$	3.1 ± 0.63	3.3 ± 0.76	$3.7^{*\#} \pm 0.65$
FEV1%	$82.3^{NS} \pm 4.6$	82.71 ± 4.4	83.6 ± 4.2	$87.5^{*\#} \pm 4.1$
PEFR (L/Sec)	$4.2^{NS} \pm 0.7$	4.2 ± 0.8	4.3 ± 0.6	$4.8^{*\#} \pm 0.9$
MVV (L/min)	$92.2^{NS} \pm 8.7$	93.4 ± 7.9	93.4 ± 8.2	$98.6^{*\#} \pm 8.7$
BHT (sec)	$25.4^{NS} \pm 4.3$	26.1 ± 4.4	26.1 ± 4.2	$29.8^{*\#} \pm 4.4$
RR (breath/min)	$18.1^{NS} \pm 2.4$	17.8 ± 2.1	17.8 ± 2.2	$16.1^{*\#} \pm 2.1$

[mean ± SD; $n = 50$; compared to 0 week $^*P < 0.05$; compared to control participants # $P < 0.05$]

3.3 Influence of Yogic Asana on Pulmonary Functions

The pulmonary function tests exhibited significantly greater FVC, FEV1, PEFR, MVV, and BHT; and lower RR in the yoga participants at the end of the investigation (12 weeks). Further, significantly higher level of FVC, FEV1, PEFR, MVV, and BHT; and lower RR was noted in the yoga participants in comparison to the control participants after 12 weeks of study. No change in FVC, FEV1, PEFR, MVV, BHT, and RR was noted in the control participants after 12 weeks of study (Table 4).

4 Discussion

It is believed that yoga helps to keep good health and physical fitness. This investigation showed lower body fat among the yoga participants at the end of 12 week of study. Further, the yoga participants showed lower body fat in comparison to control participants after 12 weeks of study. The probable cause of lower body fat among the yoga participants might be a high level of yogic exercise. The flexibility of limbs and stretching of different body parts are part of yoga exercise, this might be the possible reason of lower body fat of the yoga participants. Further, control participants exhibited no significant change in body fat, body mass, BMI, BSA, and LBM at the end of 12 weeks of study. It can be stated that the volunteers of the control

group were restricted from yoga; therefore no change in body composition variables were observed among them. Many researchers reported reduction in body fat after yoga training [17, 18]. It was suggested that higher body fat can increase the risk of obesity, diabetes, and many other complications [17, 18]. Practice yoga exercise may help to maintain normal body fat and lowers the risk of obesity, diabetes, etc., which is essential for a healthy lifestyle.

The cardiovascular fitness is assessed by measuring heart rate and blood pressure. Maintaining normal cardiovascular fitness as indicated by heart rate and blood pressure are essential criteria for good health. The cardiovascular response to yoga exercise was investigated in this study. The yoga participants showed significant reduction in systolic blood pressure (SBP), diastolic blood pressure (DBP) and resting heart rate (RHR) after 12 weeks of yoga training. Further, the yoga participants showed decline in SBP, DBP and RHR in comparison to control participants after 12 weeks of study. It can be stated that yoga involves physical activities (asanas), and breathing exercises (prayanama) which might be the cause of reduction of blood pressure and heart rate of the participants after 12 weeks of yoga training. However, no significant change in blood pressure and heart rate was observed among the participants of the control group after 12 weeks of study. The possible reason for the unaltered blood pressure and heart rate among the control participants might be that they were restricted form yoga exercise. Many researchers observed reduction in blood pressure and heart rate after yoga training [19, 20]. The comparison of the effective score for blood pressure and heart rate between yoga and control participants revealed that the long-term intervention should be made to observe the effects of yoga on cardio-respiratory system [21–23]. Decline in heart rate and blood pressure indicate the parasympathetic activity [19, 20]. An elevation in heart rate and blood pressure increase the risk factors for cardiovascular disease [23]. It can be stated that yoga practice restores normal cardiovascular activities and helps to maintain good health. The practice of yoga maintains normal cardiovascular status and thus helps to keep good health.

The lung functions are essential for assessing the respiratory status of the subject. The respiratory functions in response to yoga were studied in the present experiment. There was significant increased in FVC, FEV1, PEFR, MVV and BHT and significant reduction in RR among the yoga participants after 12 weeks. It can be stated that yoga involves asana (posture- physical exercise), pranayama (breathing exercise) and meditation (an approach to training the mind) might be the cause of improvement in lung functions at the end of 12 weeks of yoga practice. It is suggested that yoga exercise involves postural changes and contractions of respiratory muscles which might strengthen the respiratory muscles and thus improve the lung functions. The yoga participants showed significantly greater FVC, FEV1, MVV and BHT; and lower RR in comparison to control participants at the end of 12 weeks. The higher FVC, FEV1, MVV and BHT; and decreased RR might be due to the effects of yoga practice performed by the volunteers of the yoga participants compared to control participants. However, no significant change in lung functions was observed among the control participants after 12 weeks of study. It can be suggested that as the volunteers of the control group were not engaged in yoga therefore, no change in respiratory functions

were observed among them. Many researchers reported similar observations [3, 10]. Regular yoga practice resulted in decrease in resting respiratory rate, improvement in BHT and MVV [6, 24]. During performing Kapalbhati involvement of the abdominal muscles and diaphragm causes increase force of contraction of the respiratory muscles resulting in forceful expiration [6]. This produces powerful exhalation in quick succession and causes abdominal and diaphragm muscles contraction and to make full use of these muscles during prayanama [6, 24]. Thus regular yoga practice increased the activities of respiratory muscles and hence improved lung functions. Alternate nostril breathing (Anulom-vilom), a part of pranayama increases the functions of respiratory muscles and thus improve the respiratory functions as indicated by FEV1. Variation in breathing during pranayama might cause the respiratory apparatus to empty and fill quickly, completely and efficiently which may intern increase forced vital capacity (FVC) [6, 24]. Pranayama, may stimulate the respiratory centre which is responsible for improvement in the voluntary breath holding time (BHT) and lowers the resting respiratory rate (RRR) [6, 24, 25]. Meditation has a calming effect on the mind and may reduce emotional stresses, by withdrawing the bronchoconstrictor effect [6, 24]. Thus regular yoga practice may improve the pulmonary functions and maintain good health.

5 Conclusions

The children and adolescent age group spend a considerable span of time in school. Schools play an essential role in helping children and adolescent to develop social and academic skills that are required to be successful as adults. Regular practice of yogic asana, pranayama, and meditation improves the fitness which mediated by lowering body composition and improving cardiopulmonary functions. The results of the present investigation suggest that yogic practice can improve life-style and reducing the risk of obesity and cardiopulmonary diseases among adolescents. The present study demonstrated that yoga practice among school children and adolescents may be an effective measure to develop fitness and health and reduce stress and strain which may reduce their performance. Practicing yoga can minimize injuries and health issues associated with of doing repeated tusk and enhance work performance. Yoga practice among the adolescents may increase physical fitness, health, and maintain disease free lifestyle, which in turn develops personality to become a good citizen in future.

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The Approach Depiction of Interaction and Effective Waste Management Planning Design for Sustainability

Lipika Basumatary, Sandipan Bhattacharjee, and Bhaskar Saha

Abstract Systematic waste management is an essential criterion for societal harmony as absence of it in recent times could lead to troublesome conditions for common people residing in urban and sub-urban areas of a particular place due to communication and awareness gap between concerned authorities and the masses. The implementation of technologically advanced garbage bins has been already proposed as a solution for the matter. To address the issue projected, a systematic planning design is essentially required that would be implemented through concepts of user interaction while also ensuring proper user experience to create a transparent scenario among the users. This paper aims at studying the user perception for proposal of an organized planning design that would address the communication gap that has been existent amid the users. The planning design would essentially deal with proper waste management in a particular area and the perception of the users on it was tallied through a questionnaire-based survey in Assam, India. The study also ventures through aesthetic aspects in regards to cleanliness and ensuring prospective for sustainable environment in the long run.

Keywords Technology · Planning design · Management design · Interaction design · Sustainability

1 Introduction

Economic activities and urbanization have brought about a hike in population of the entire world and along with it there has been a noticeable rise in the solid waste of societies. The urban areas are the major contributors of solid waste and reports suggest that by the year 2025, the number would reach around 1.8 million tons per year [1, 2]. Authorities concerned with dealing of the issue have worked promptly and efficiently with both man power and capital to address the problematic aspects [3]. According to a report, Task Force on Waste to Energy released in 2014 under

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Table 1 Estimated waste generation of Urban India

Estimated waste generation (TDP)	Year
2,76,342	2021
4,50,132	2031
11,95,000	2051

the Planning Commission estimated that urban India which comprises of 31.16% of the total population will generate 2,76,342 tons per day (TPD) of waste by 2021; 4,50,132 TPD by 2031; and 11,95,000 TPD by 2050 [4] Table 1.

In a densely populated country like India, the management of solid waste which comprises of collection, transportation and disposal has been a major issue. The Municipal Solid Waste (MSW) generated is dumped mainly on the outskirts and low-lying areas which violates the practice of sanitary landfilling. Such practices may result in surface water contamination during the monsoon season due to flooding and ground water contamination through percolation of sludge [5, 6]. Various researches show that the solutions for proper solid waste management, which were based on the maximum yield upon its degradation have lacked to address the actual goal. The solutions were initially on environmental cleanliness and preservation [7]. According to Röhrs et al., the developing countries with upcoming economic infrastructure have less priority towards the aspect of solid waste management. As a result, the inconveniences created are troublesome for the people residing in a particular urban neighborhood. The sanitation of a particular region is mostly affected with improper managing of waste materials [8]. Developed countries essentially emphasis on the aspect of waste management as a concept of sustainable environmental development, while the developing nations still focus on the outcomes and raw materials obtained from the waste segregation sector that are often social or economic [9]. With improvement in lifestyle of the people in India, waste generation has also increased drastically and now there is a sheer requirement for more last for proper treatment with dumping of solid wastes [10, 11].

Due to the overflowing of the waste material in the outskirts of urban areas, the neighborhoods in that particular area face the problem of sanitation and foul odor around the place [12, 13]. Improperly structured management of waste in collection and transportation are the major reasons for accumulation of solid waste in various corners of the urban area even at places where garbage bins are available [14]. The management sector itself in India is going through a critical phase as the concerned authorities sometimes are unaware of and are late to respond to such overflowing areas with solid waste, due to a communication gap, created between the public and concerned bodies of the issue in hand [15, 16]. The Urban Local Bodies (ULBs) governs the Municipal Solid Waste (MSW) in India and are supposed to abide by the rules of the Municipal Solid Waste (Management and Handling) Rules (MSWR). Unfortunately, majority of the ULBs do not possess the appropriate action plans as well the resources for the execution of the rules suggested by the MSWR [17]. A proper communication mode for interaction between the public or residents of an

Fig. 1 Solar powered trash compactor by ECUBE LABS [29]

area with the concerned authorities regarding notification and forwarding of news of untreated solid waste, is essentially required to address the issue [18, 19] (Fig. 1).

The problem of waste management has grown in recent times and to solve it, several innovative approaches and models have been put forward such as planning models for proper sanitation and cleanliness of a particular area [20–22]. In a very futuristic approach smart dustbins are proposed for urban areas and neighborhoods that could prove to be very efficient in keeping the area clean and waste free to an extent. These garbage bins come with inbuilt sensors to detect waste levels inside the bin and compresses it automatically using the solar energy and hence solves the problem of overflowing of solid waste in the area. These bins are mostly compact and easy to unload for seamless waste transportation. A platform for direct communication with the concerned authorities is also elaborated with the concept of these technologically advanced garbage bins that allows the people residing in nearby areas to reach out to them accordingly Fig. 2 [23–25].

In this paper, it was intended to explore the practical implementation of technologically advanced garbage bins in a particular place through a comprehensive user survey. As improper management of waste leads to inconveniences and health hazards while also polluting the environment, it is essential to know the user perception of having a innovative interaction platform that could address the issue. The study would also essentially venture through the possible areas of proper waste management interaction for a hygienic and clean neighborhood. The goal was to enquire about the user perception of a systematic planning design of a platform for better

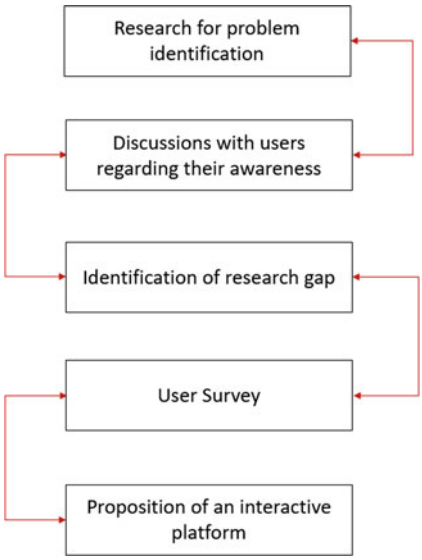

Fig. 2 Follow diagram of design process and methods

communication with concerned authorities for efficient waste management. To have a broader understanding of the actual usability and functionality of the proposed platform, it was essential to know the user perception regarding it. The user perception was tallied through a questionnaire-based survey in Tezpur, Assam, India among seventy individuals, regarding the problems they regularly faced in the locality.

The aim of the study is to justify the necessity of a innovative platform towards proper solid waste management in a particular urban area through the concepts of user interaction and communication. The objectives that are sought to be achieved through the approach extensively rely on user ease for waste disposal, clean and clear areas with minimal waste accumulation, hygiene of a society of the particular chosen place and also environmental aspects are considered. The study also ventures through the aesthetic development of the particular area, such as the look and feel of the neighborhood, where the approach has been made.

2 Design Process and Method

The above flow diagram shows the design process and methods for carrying out the study for the need for a platform for communication between user and the concerned authorities or bodies to address the issue of solid waste management Fig. 3.

Fig. 3 Discussion with users

2.1 Methodology

In correspondence to the initial discussion there exists multiple scenarios where solid waste has been a major threat to the environment as well as society. It could lead to various risks related to health and environment. To reduce the negative impacts under 74th amendment of the constitution of India the urban local bodies were given the authority to govern the solid waste management. Various Decentralized Municipal Solid Waste Management Systems were initiated by various ULBs and State Government. The main goal was to manage the waste and keep the damage to minimum. However, lack of funds demotivated the coordinators to perform the obligatory function. Cities have different characteristics depending on the size of the population and area hence different approaches and models are needed to control the system. A proper study and planned model is required to come up with a systematic management. Insufficiency of staff with technical expertise narrowed down the influence and limited the number of tasks assigned to them. Lack of sense of responsibility and awareness of citizens towards waste management resulted in a huge communication gap and has led to its inefficiency. One of the major causes of its failure is the inability of the system to involve one of the primary waste generators. Involvement of the public has the highest potential of reviving the approach because of the population that has been increasing over the years provided the approach is economically sustainable.

To explore the issues and problems, discussions were made with users who lived near the dumping sites. According to the response collected from the users most of the problems were related to the environment and health Fig. 3. The sites were not visually pleasing and the uncollected solid waste produced foul odor. The overflowing garbage from community garbage bins used up fairly large amount of spaces that could have been utilized otherwise. The rag pickers who have a major role in recycling and reusing items and the workers who are involved in picking and handling waste i.e. workers who are in contact with the wastes are affected directly. The public residing within the surrounding area of the dumping ground are affected indirectly from breeding of disease vectors like flies, mosquitoes and rats. The major threat for

the environment by waste disposal is its contribution to pollution. Various noxious gases like Sulphur Dioxide (SO2), Carbon Monoxide (CO), Respirable Suspended Particulate Matter (RSPM) and Suspended Particulate Matter (SPM) are emitted from solid waste. The dumping of waste can also be a problem for the people living in and around the site that are depending upon the ground water for drinking and other domestic purposes since the activity could contaminate the water. In addition, uncollected solid waste can also become the breeding ground of diseases like Diarrhea, Malaria, etc. as it could obstruct storm water runoff resulting in the forming of stagnant water bodies. Along with the various negative impacts caused to the environment it also degrades the aesthetic beauty of the neighborhood and restricts the development.

According to the discussions made with the users, the most prominent aspect that might be the base of improper management of solid waste in the neighborhood leads to the communication gap between the users and the concerned authorities. The lack of proper communication structure has led to some of the pertaining issues related to waste management in the society. When the garbage bins are full at a point of time, there must essentially be a way to notify the concerned authorities rather than their usual collection of waste in designated time periods. The public of the concerned area, who are the users of the service must have a mode of control over the matter. The negative effects caused by accumulation of waste in societal areas, should be addressed promptly with the help of technology and proper planning.

A hypothetical proposal of an interactive platform that enables the users to have a mode of control over the solid waste management, is presented with the idea that with mode of control it would also provide awareness and information to the people of the locality. The proposal would be primarily based on the aspects of user interaction with technological devices, applications and websites. Implementation of smart garbage bins could be a futuristic approach towards solving the issue. At times, when there is a case of overflowing garbage bins in the locality, any person connected with the user interfaces could notify the concerned authorities in a quick time. The garbage bins installed could also automatically send notifications to the bodies for waste collection and transportation. The bins would also be capable of automatic indication of waste materials in itself for a period of time. The proposal would essentially bring about changes in human behavior and perception towards proper solid waste management in societal domains. The primary goal of the approached proposal is to eliminate the communication gap that is existent in context to our society and people living in those regarding proper solid waste management, through user interactive mediums and platforms.

To validate on the proposed approach, the practical feasibility and implementation of the idea must be tallied to understand the user perceptions regarding it. It was essential to understand the needs of the users in regards to waste management of the particular neighborhood. A questionnaire-based survey was conducted among seventy individuals irrespective of their age, gender and profession in Tezpur, Assam, India Fig. 4. The questions were quoted to enquire about the awareness and promptness of people in the locality regarding solid waste management. It was also to enquire about their perception on the unnecessary accumulation of waste materials

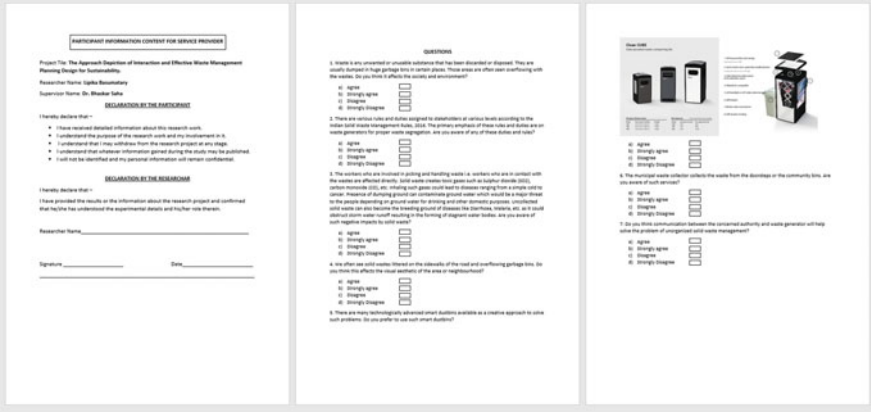

Fig. 4 Questionnaire for survey

in the outskirts of the urban areas. The questions would also address the issue of lack of communication among the users and concerned bodies.

The first question was framed in order to understand the users' consciousness if they realized that the society and environment were affected due to the waste.

The second question focused on understanding the level of the awareness of the waste generator about certain rules and duties assigned to various stakeholders by the ULBs.

The third question listed various negative impacts that were caused due to solid waste and enquired about the knowledge of the user regarding such effects to the environment and health.

The fourth question dealt with understanding users' perception regarding the influence of visual aesthetics of the locality.

The fifth question mainly aimed at investigating the commitment of the user for the utilization of multipurpose smart dustbins.

The latter question aimed at understanding their awareness and realization of the services that were provided through the proposed hypothetical planning approach.

By the commencement of the seventh question the users have realized the importance of awareness and involvement of the waste generators in a common platform for a better management system. Hence the question was framed in order to understand their perception about their participation if such platform was provided (Fig. 5).

3 Result and Discussion

According to the user survey, the feedbacks were recorded for upgradation of the concept. The data generated from the feedbacks is presented in a graphical form Fig. 6.

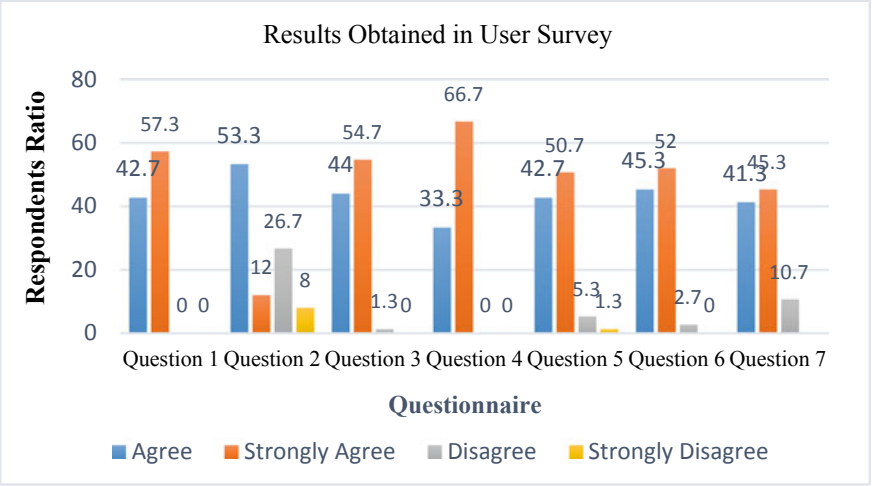

Fig. 5 Results obtained in user survey

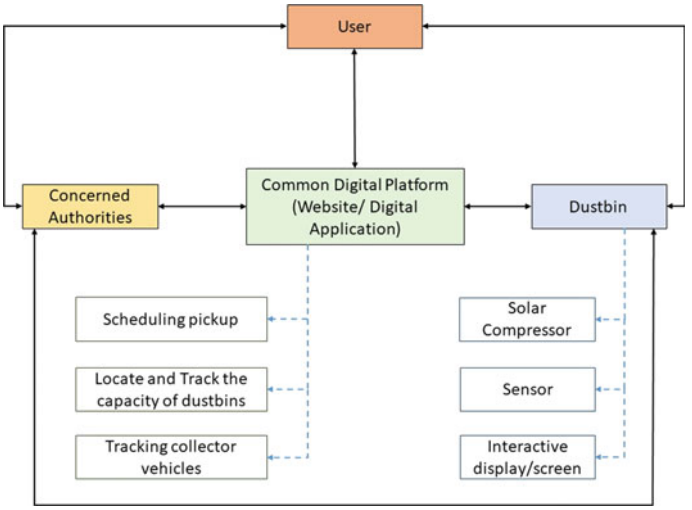

Fig. 6 Flow diagram of interaction between user and concerned authorities

According to the responses collected for Question 1, 57.3% of the total responses strongly agreed that solid waste affects the society an environment. And the remaining 42.7% agreed as well. It has been observed that none of the user denied the statement. For the second question 53.3 % agreed and 12% strongly agreed about being aware of the duties and responsibilities given to the waste generators. The remaining 26.7% disagreed and 8% strongly disagreed about being aware of any such rules. Question 3 was focused on exploring the users' knowledge about the negative impacts by solid

waste to which there was a positive response. 54.7% strongly agreed and 44% agreed about being aware of such impacts. Whereas 1.3% of the users disagreed on having any awareness of such effects. In question 4, 66.7% strongly agreed and the 33.3% agreed that littering and overflowing of garbage bins affects the visual aesthetic of the site as well as the locality. The following Question 5 aimed at understanding the preference of users of using smart dustbins. To which 50.7% strongly agreed and 42.7% agreed to use if ever given the choice. The remaining 5.3% disagreed and 1.3% strongly disagreed about using such dustbins. For Question 6, 52% strongly agreed and 45.3% agreed about being aware about the various services given to the public for efficient solid waste management. 2.7% of the user responses disagreed about knowing about such services. The last question i.e. Question 7 aimed at understanding their perception about the proposition provided. 45.3% strongly agreed and 41.3% of the responses agreed that such a proposition would be successful and the remaining 10.7% disagreed that removing the communication gap would not yield better results.

From the data received, it was evident that the users deliberately needed and wanted a mode of communication with the concerned authorities. The users had knowledge about the innovative approaches made by various organizations and the government to have a proper structure of solid waste management. The users also had scenarios where they could relate to accumulation of solid waste in their neighborhood. They wanted a platform where all the aspect regarding solid waste management could be meet with a solution through user interaction and involvement. The implementation of technologically advanced garbage bins was also accepted by the users as those would essentially be a boost in managing solid waste materials in a society. Users also agreed on the aspect of visual aesthetic that constitutes to look and feel of a neighborhood. The approach would essentially bring about clean and clear neighborhoods in the society.

The garbage bins would primarily have solar compressors that would compress the filled garbage to make room for some more to be filled up. There would be sensors that would help the solar compressors to work accordingly. The garbage bins would also have interactive displays or screens that would display informative visuals and advertisements which could be used for awareness as well as generating revenue. All the levels of the interaction design would ultimately be connected with the concerned authorities who would have control over the platform.

The scope of such interaction design lies in many domains of the society and could be enhanced or modified in the future to deal with societal issues related to waste management accordingly.

The following Fig. 7 is a user flow diagram for the proposed interactive digital platform. The users would be able to connect and communicate with the concerned authorities and among themselves directly. The platform would enhance the management system and their services such as picking up garbage from door of the user. It would also notify the status of the nearby dustbin which would prevent the overflowing. The implementation of the proposed interactive platform would act like an upgradation of the current waste management system and therefore fill the communication gap between the users and the responsible authorities.

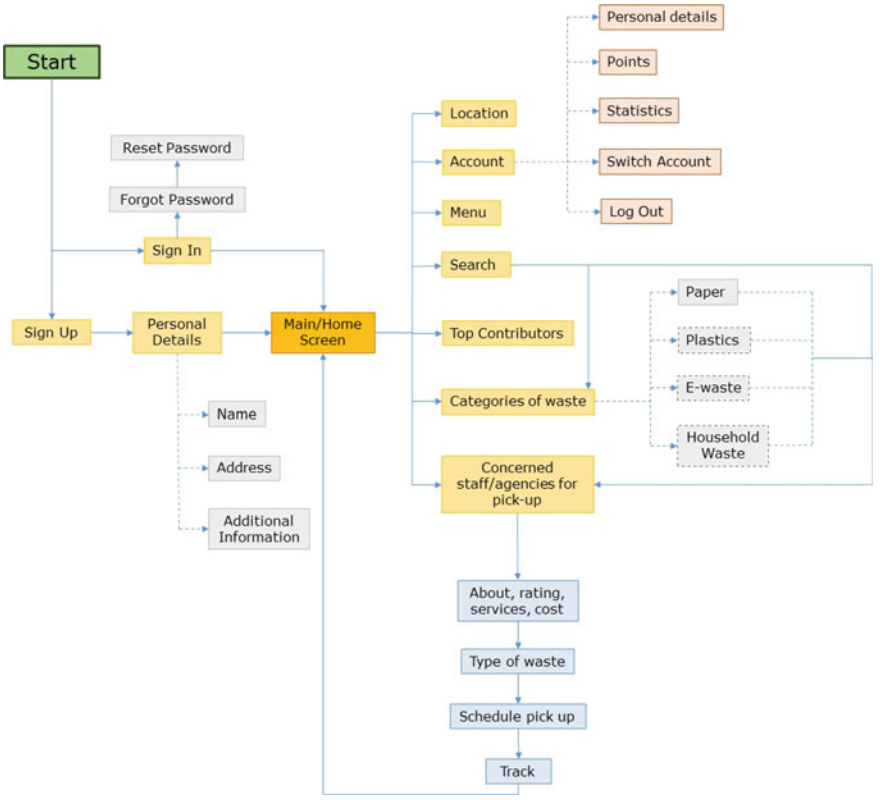

Fig. 7 User Flow diagram of the proposed interactive platform

4 Conclusion

While addressing the issues related to solid waste management in the societal domain through a hypothetical planning design approach, a number of critical obstacles could possibly be solved such as accumulation of solid waste in neighborhoods, foul odor and environmental pollution, and issues related to sanitation and hygiene. Through the above investigation on the need and want of an innovative mode and platform for addressing the communication gap between users and concerned authorities, could prove to be very beneficial to society. The novelty of this paper is to propose a hypothetical planning approach for proper waste management, through a interactive platform. The technologically advanced garbage bins could be a buff to the entire proposed approach, while also establishing an aesthetic scenario around the neighborhood. By the implementation of ideas and perspectives of technology in the sector of waste management through user interaction, might raise the possibility of coming out with innovative service and planning designs. The collaboration of students and people from various technical and aesthetical fields would be necessary

and vital. With the possible scope of future work, could prove to be a helpful tool to the masses. Extensive and intensive work on the elaboration of potential of such an approach establishes a future possibility that it could be used for larger areas for implementation and hence would create a scope for an aesthetically sound, clean and hygienic environment.

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A Study on the Discomfort Experienced by Foundry Workers and Automation for Reducing the Discomfort

Asif Mahammadsayeed Qureshi and Darius Gnanaraj Solomon

Abstract Metal casting foundry involves many activities that are prone to the ergonomic risk of musculoskeletal disorders (MSDs). This study finds the biomechanical load experienced by workers involved in manual metal pouring activity in small-scale foundry units and suggests an ergonomic intervention in the form of an automation system to reduce the biomechanical load. A sample of 12 workers involved in metal pouring activity from different foundries from western India is selected for analyzing biomechanical load. The biomechanical analysis is carried out using DELMIA-V5 software. The results indicate that the average compressive load on L5/L4 lumber for the selected population is 4365 N which is more than the limit of 3400 N specified by the National Institute of Occupational Safety and Health (NIOSH). The ergonomic risk is reduced by replacing manual activities with an automated system. A design of an automated ladle system for pouring molten metal is presented. The automation of metal pouring activity reduces the ergonomic risk and improves workplace safety. It is estimated that the cost of automation is 6 lakh rupees and the return of the investment will be 25% per year.

Keywords Foundry · Musculoskeletal Disorders (MSDs) · Biomechanics · Automation

1 Introduction

Metal casting is the most commonly used formative manufacturing process. Sari et al. (2016) reported that small and medium enterprises contribute to the growth of Indonesia. 63 participants took part in a study on the risk assessment of Aluminium Foundry using an ergonomic approach. The study found that the workers suffer

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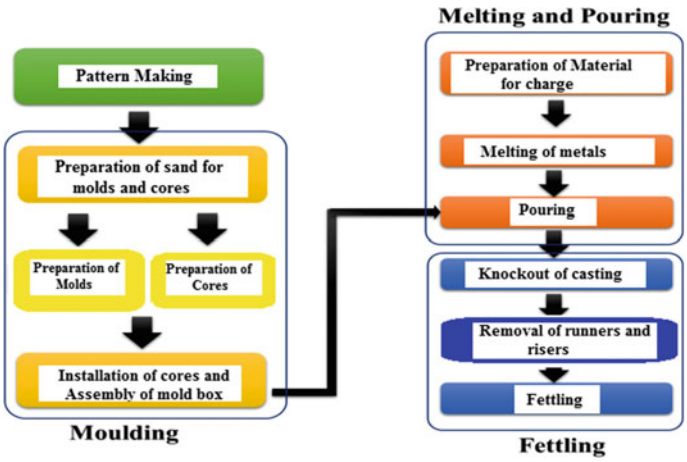


Fig. 1 Foundry operation flow chart

from workplace musculoskeletal disorders, work injury, poor indoor air quality, and hazardous machining operations [1].

Musculoskeletal Disorders (MSDs) are injuries and disorders which are resulting from exposure to manual material handling tasks [2]. The costs associated with MSDs are considerable and need ergonomic improvements to reduce the same [3, 4]. A study was conducted in a steel foundry based in Algeria. The Nordic questionnaire was used to assess the discomfort among 30 workers. The results indicated that 51.85% of them had low back pain and 40.74% of them had shoulder pain [5].

The foundry industry involves many activities which are labor-intensive leading to ergonomic risk factors like awkward postures, repetitive motions, faster pace of work, and heavy material handling which promote MSDs during the melting, pouring and fettling activities as shown in Fig. 1.

Some of the major manual materials handling activities are: handling molten metal, handling molding sand, movement of the mold box, movement of castings, and taking raw metal to the furnace. Full automation of these activities is possible in small and medium-scale foundry units. It was shown that demanding tasks performed physically during foundry operations lead to the risk of MSDs [6, 7]. The risk of MSDs can be assessed using a wide range of methods which can be categorized as Self Reports, Observational Methods, and Direct Measurements.

The biomechanical analysis combines engineering mechanics, anthropometry, and physiology through mathematical relationships. Biomechanical models are used to analyze the torques and forces on several parts of the body. These forces are then compared with muscle strength limitations to predict a stressful work posture that may lead to MSDs. Biomechanical analysis is useful for activities involving large forces and awkward postures. Data obtained by direct measurements such as EMG, force measurement can be used for biomechanical analysis. Many studies are available related to biomechanical analysis in different sectors. Ray et al. [8]

carried biomechanical evaluation of workers involved in various construction activities using software and found compressive loads at L4/L5 joint above the threshold limit. Nimbarte [9] analyzed biomechanical load on the neck of workers during a lifting activity using Electromyography (EMG) system. Southard et al. [10] presented ergonomic interventions in beef weighing activity using biomechanical analysis. Jin et al. evaluated biomechanical loads experienced by workers involved in bush crop harvesting [11]. The studies on biomechanical analysis in foundry industries are rare to find in literature. Nowadays software is used in every field of engineering. As direct measurement techniques require costly equipment, it is convenient to use software for biomechanical analysis. The commonly used software for ergonomic analyses by ergonomists: CATIA-V5, DELMIA-V5, 3D-SSPP, and JACK-V8.4. These tools are used for postural analysis, reach analysis, lift and carry analysis, push–pull analysis, and biomechanical analysis [12].

The foundry process of pouring molten metal in mold induces high stresses on the joints of workers, particularly at the low back. It is one of the hazardous tasks in the foundry that leads to the risk of MSDs and accidents. Biomechanical analysis of this activity is useful to quantify the risk of MSDs and design suitable interventions. Automation in the manufacturing industry not only increases the rate of production but also improves the quality of production and safety at the workplace. Automation decreases the biomechanical load and reduces the risk of MSDs [13]. Lock et al. compared the biomechanical load resulting from semi-automated and manual systems in an automotive component manufacturing industry [14]. Many material handling processes can be automated to reduce the risk of MSDs. Kampa and Golda reported the effect of automation on Overall Equipment Effectiveness (OEE) using software simulation in the fettling activity of foundry [15]. Birkhold et al., present a model-based Numerical controlled (NC) system for metal pouring suitable for batch production [16]. From the foregoing discussions, it is seen that there are very few studies available in the literature on biomechanical analysis and automation of small-scale foundries to reduce ergonomic risk. The work reported in this paper is carried out with the following objectives;

1. To assess the biomechanical loads during manual metal pouring activities using DELMIA-V5 software
2. To propose an automated system for metal pouring activity to reduce MSDs experienced by foundry workers.

2 Materials and Methods

Biomechanical analysis is used to quantify biomechanical loads on workers involved in metal pouring activity from the melting department. The biomechanical analysis is carried out using DELMIA-V5 software. An automated metal pouring system is proposed which reduces the ergonomic risk associated with metal pouring activity. 12 workers involved in metal pouring activity from different foundry units are analyzed using the biomechanical analysis software. These are small-scale foundries with no

Table 1 Demographic information of study population

No.	Data	Min.	Max.	Mean (SD)	
1	Age (years)	21	50	32.75 (8.93)	
3	Height (cm)	163	170	166.58 (2.27)	
2	Weight (kg)	51	70	60 (5.97)	
4	Foundry experience (years)	3	11	5.5 (2.50)	

automation situated in the western India region. The subjects are males ranging from 20 to 52 years old. The willingness of the foundry owners and workers was taken before the study. Table 1 provides the demographic data of 12 subjects.

2.1 Biomechanical Analysis

Biomechanical analysis uses the laws of physics to describe biological phenomena in the human body. The information needed for the analysis of any material handling activity is the load to be lifted, its direction and position, body posture, and body segment parameters. In lifting activity, the disc between the fifth lumbar and first sacral vertebrae (L5/S1 or L5/L4) is the most susceptible to injury. In biomechanical analysis, mostly the forces and moments at L5/L4 are calculated and compared with safe values specified by NIOSH. Initially, a free body diagram is drawn based on the posture and body segment dimensions. Then segment by segment, force analysis is carried out using simple trigonometry. Figure 2 illustrates the procedure for theoretical calculations of biomechanical load in simple box lifting activity. For equilibrium at wrist, conditions to be satisfied are;

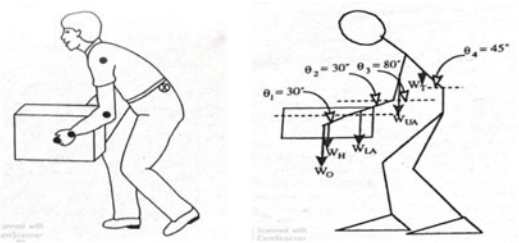
$$\Sigma F_X = FX_W = 0 \tag{1}$$

$$\Sigma F_Y = FY_W - W_0 - W_H = 0 \tag{2}$$

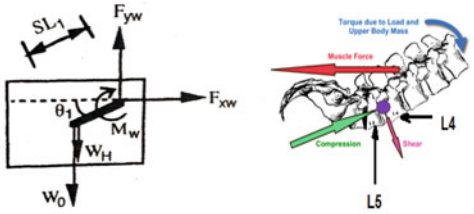
$$\Sigma M_W = M_W - (W_0 + W_H)SL_1 Cos\theta_1 \tag{3}$$

Using these relations, values are calculated at the wrist, lower arm, upper arm, and trunk segments. The compressive force and shear force at L5/L4 are calculated.

Theoretical calculations of biomechanical load are tedious and time-consuming. In this study, DELMIA-V5 software is used to calculate the biomechanical load. Before conducting the analysis of the activity under this study, a sample box lifting activity shown in Fig. 2a was analyzed using both theoretical calculations and software. The compressive force on L5/L4 calculated by both the methods was found to be almost the same with a negligible variation of 0.54%. Out of the various activities involved in the work cycle as shown in Fig. 3, the posture for metal pouring activity



(a) Actual Posture (b) Free body Diagram



(c) Free Body diagram of hand segment (d) Direction of forces

Where,

W_O	Weight of the External Load in N
W_H	Weight of a hand in N
M_W	The resultant moment acting at the wrist N-mm
FX_W	The resultant force acting on the wrist in the X direction
FY_W	The resultant force acting on the wrist in the Y direction
θ_1	Angle made by the hand with horizontal
SL_1	Length from wrist to the center of mass of hand

Fig. 2 Illustration of biomechanical load [17]

was very awkward, and postural analysis indicates a very high-risk level (REBA Score 11). This activity was selected for biomechanical analysis.

The introduction of computer simulation tools and their advantages were studied in Rostov foundry. The system developed increased production by 6.9% and reduced the defects by 5.1% [18]. The photographs of subjects in actual working posture are used as the base for building manikins in the software. The actual height of the subject is used as the reference anthropometric data. The other body segment dimensions are decided by the software using standard proportions relevant to height. The weight of the ladle is 60 kg. Figure 3 shows the actual photographs of the activities and Fig. 4 illustrates a manikin model used for software analysis.

The compressive force and shear force at L5/L4 was recorded. Sharma et al. (2020) conducted a biomechanics analysis conducted in a work environment of a foundry. The spine compression values were found to be lesser than the recommended limits, validating that the proposed fettling booth models as control measures in tandem with the designed prototype [19]. In the construction sector, Ray et al. (2015) studied

Fig. 3 Photographs of workers involved in metal pouring activity

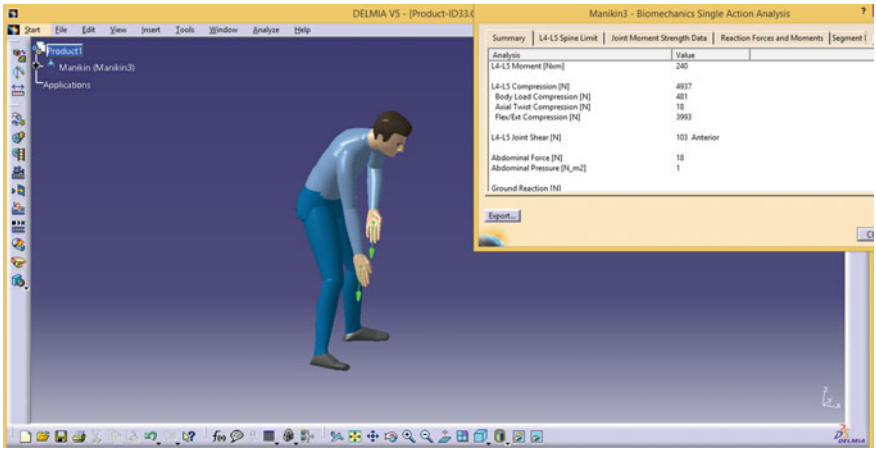


Fig. 4 Manikin and biomechanical analysis in the software

biomechanical load on 3 laborers involved in jack pipe lifting activity [8]. The average compressive force on L5/L4 lumber during a work cycle was found to be 4540.8 N. This value is close to the mean compressive force of 4364 N resulted in the workers involved in melting and pouring activity reported in this work.

In one of the study by Akhtar et al. (2020) energy expenditure prediction program software was used to evaluate the operations in a foundry shop. The activities and time taken during the operations were recorded to find the energy expenditure. The software analyzed the recorded data. This method is more accurate and feasible and less costly than laboratory techniques like measurement of oxygen consumption and EMG. The technique helps researchers to gauge worker's fatigue. In this study, the operations and the less hazardous postures were identified. Modifications were suggested in the posture, process, and system for reducing the rate of energy expenditure [20].

2.2 Automation

Bansode et al. (2019) carried out a study and found that all the manual processes in a foundry, rejection analysis, and cause-effect analysis. Automation of dipping, coating, and drying cycles in each mold reduced the rejection from 11.2 to 3.5%, the cycle time from 4–5 days to 2–3 days, and increased productivity from 27 to 32% [21]. Wadhwa (2012) did a case study of flexibility in automation of the Norwegian foundry industry [22]. The study identifies the suitability of manufacturing flexibility to a foundry setup by implementing automation and presents the set of design rules for foundry automation and assist flexibility in manufacturing. Misztal et al. (2015) discussed the human role in foundry automation and suggested the type of activity which can be automated and about automation and human role [23]. To reduce the ergonomic risk during metal pouring activity, a semi-automatic metal pouring ladle is proposed. Three design iterations are done and the final one is selected after incorporating suggestions from actual end-users and foundry supervisors. The actual metal pouring activity involves different tasks as mentioned in Table 2.

The pouring activity can be divided into three main tasks – taking the ladle to mold, position the ladle, and tilting the ladle for pouring the molten metal into the mold. These three tasks can be carried out using an automated system. Carrying the ladle to mold position is considered as X-axis travel on guided rails and positioning the ladle with height adjustment is considered as Y-axis travel (Fig. 5). Linear motion necessary for tilting ladle is considered as Z-axis travel. The X-axis and Y-axis travel movements are performed using servo motors whereas Z-axis motion is obtained using an electric linear actuator. It is assumed that the mold position is fixed to suit the use of the automated system.

The design calculations are carried out to decide the speed, torque, and power. The dimensions of various components such as a lead screw, supporting bracket, and shaft are decided according to the standard design procedures. Table 3 gives the details of major parameters considered for design calculations. These assumptions are based on an actual work system where the activity is carried out and the feedback

Table 2 Tasks involved in metal pouring activity

Sl. No.	Activity details	Time	Remark
1	Standing till ladle on the stand is filled with molten metal at the furnace	16 s	Normal Static posture with no load
2	Lifting the ladle from the stand and carrying to mold location (10–12 m away)	16 s	Walking with load
3	Position the ladle, tilt the ladle, and pour the molten metal into the mold	14 s	Awkward posture with load
4	Carrying the ladle to the next adjacent mold	5 s	Walking with load
5	Positioning the ladle, tilt the ladle, and pour the molten metal into the second mold	15 s	Awkward posture with load
6	Taking empty ladle to the furnace	19 s	Walking with less load
	Total cycle time	85 s	

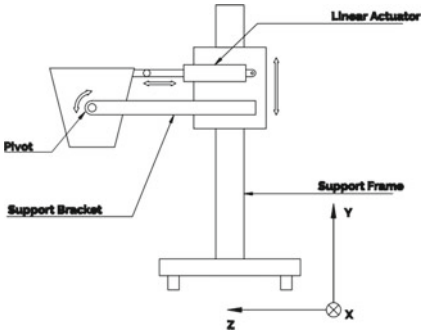


Fig. 5 Schematic of an automated system

Table 3 Parameters of the automated system

No.	Parameter	Magnitude
1	Linear velocity of horizontal travel (in X-direction)	500 mm/s
2	The linear velocity of vertical travel (in Y-direction)	3 mm/s
3	Linear velocity of actuator (in Z-direction)	20 mm/s
4	Weight of ladle with molten metal	60 kg

from workers and supervisors. The proposed design is modeled using a computer-aided design software Unigraphics-NX. The model is checked for static strength using finite element analysis software ANSYS-R12.

3 Results and Discussions

Subjects selected from the melting department were analyzed for the biomechanical load. Table 1 shows the demographic data of 12 subjects involved in the metal pouring activity. The mean height of the study sample is 166.58 cms. (SD 2.27) and the mean age is 32.75 years (SD 8.93). The biomechanical load on each worker is calculated using the software. Table 4 gives the biomechanical loads in terms of compressive force and moment at the L5/L4 joint. The maximum and minimum compressive force is 5256 and 3158 N respectively. The mean compressive force is 4364 N (SD 910). The NIOSH action limit for the compressive force at L4/L5 joint is 3400 N. Out of 12 subjects, 9 subjects (75%) are exposed to compressive force above the action limit. This indicates that the selected activity is prone to the risk of MSDs. Sharma et al. (2021) reported that awkward posture and poor working conditions are the major risk factors contributing to MSDs and lead to workplace injuries among workers in foundry units. An ergonomic analysis was conducted using digital human modeling in CATIAV5 software by simulating a digital work environment similar to the actual working conditions. The effects of table height, table width, and population percentile on the L4–L5 spine compression limit using Taguchi L9 orthogonal array were evaluated. The work table height was found to be significant, and the other factors were not significant [24].

To reduce the risk of MSD due to biomechanical overload, an automated system is proposed. Figure 6 shows the labeled 3-D model of the proposed design of the automated metal carrying and pouring system. Basic dimensions are calculated using the standard design formulae. The overall weight of the modeled ladle system carried on rails is 305 kg. This X-motion for carrying the ladle system to a specified mold position is to be achieved by a rotating wheel shaft using a servo motor. This servo

Table 4 Biomechanical load (compressive force and moment) on an individual subject

Sl. No	Compressive force at L5/L4 (N)	Moment at L5/L4 joint (N-m)
1	3834	146
2	5256	244
3	4937	240
4	5578	245
5	5241	231
6	5081	222
7	3643	145
8	3213	143
9	3158	136
10	4930	230
11	3210	112
12	4297	205

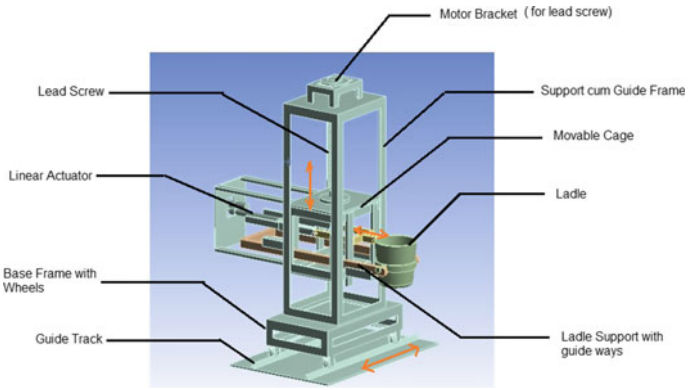


Fig. 6 The labeled model of the automated system

motor is directly coupled to the wheel shaft. The designed torque and speed required at this servo motor are 71 N-m and 100 rpm respectively.

The Y-motion for vertical positioning of the ladle is obtained using a square threaded lead screw. This lead screw is rotated by a servo motor attached at top of the support frame. The designed torque and speed at this motor are 13 N-m and 25 rpm respectively. For pouring the molten metal, the ladle is tilted about the pivot point using an electric linear actuator. The travel of this actuator in Z-motion is calculated as 250 mm and the force required is 500 N.

The 3-D model is analyzed for stresses and deflection using the finite element analysis software ANSYS. The material selected for the analysis is structural steel with a yield strength of 250 MPa and ultimate strength of 460 MPa. Considering a factor of safety of 2, the allowable stress is 125 MPa. The ladle support is fixed and a force of 600 N is applied at the center of the ladle (Fig. 7). The model is auto meshed and solved to find the von-mises stresses. Figure 8 shows the stress distribution. The maximum stress developed is 14 MPa which is much less than allowable stress. Also, the deflection of 0.1034 mm is observed at the ladle which is acceptable (Fig. 9).

The proposed system operates either in a semi-automatic or automatic mode. In the semi-automatic mode, the control panel will be in the hands of an operator who will walk along with the system and operate the system. The control panel includes the control of servo motors and actuators. This is similar to operating an overhead crane. This mode will require less complicated electronic circuitry. In full automated mode, the system will be fed with an NC program to coordinate X, Y, and Z motions. The mold position coordinates will be fixed and accordingly, the system will operate. The home position will be the location of the furnace. This will require suitable electronic circuitry to control servo motors and actuators.

In the manual pouring method, two workers are required to operate the ladle. In the proposed automated ladle system only one operator is required. Thus there will be a direct saving of labor costs. The cost of implementing an automated system will

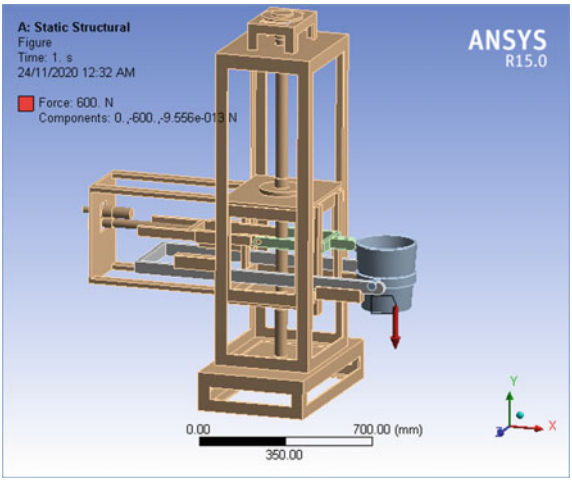


Fig. 7 Structural model for finite element analysis

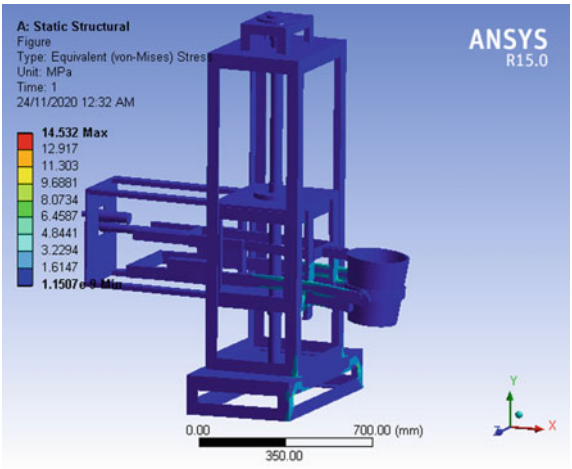


Fig. 8 Stress analysis of the model

be approximately 6 lakhs and the saving in the labor cost of one worker per year is estimated to be 1.5 lakhs.

The approximate return on investment (ROI) will be 25% which means the cost of investment will be recovered within 4 years. A further automated system also helps to add indirect costs through increased productivity, improved efficiency of the worker, reduced absenteeism due to ergonomic issues, etc. After consulting the foundry supervisors and managers, the feasibility of the implementation of the automated ladle is confirmed.

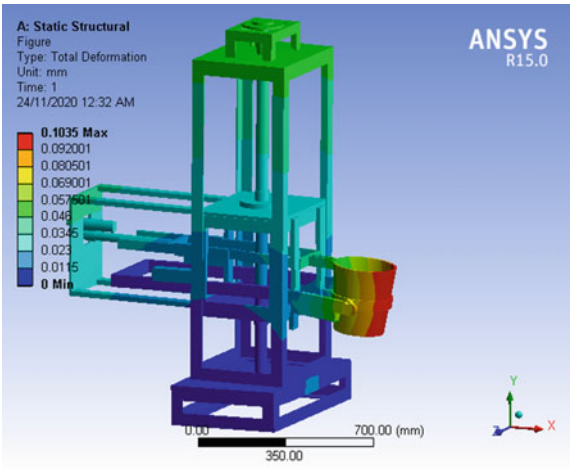


Fig. 9 Deflection analysis of the model

4 Conclusion

Biomechanical analysis has been conducted on 12 workers working in the melting and pouring section of foundry units. This study reveals that more than 75% of the workers are experiencing the biomechanical load in manual metal pouring activity above the recommended limit of 3400 N specified by NIOSH. This leads to the risk of musculoskeletal disorders (MSDs). Ergonomic risks are reduced by incorporating automation wherever possible. An automated ladle system for carrying and pouring molten metal into the mold is proposed. The return of investment for implementing automation is expected to take place in 4 years. There is scope for automation of other material handling activities in foundry units to further reduce injuries and improve productivity.

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Comparison of the Hip and Trunk Muscles Activation Between Cyclists with and Without Low Back Pain

Singh Amrinder, Manpreet Kaur, Abhinav Sathe, and Shweta Shenoy

Abstract NSLBP is the prevalent stumbling block for cyclists but still, studies investigating the cause of NSLBP and its association with abnormal lumbothoracic kinematics are scarce. The study aims to examine the difference in co-contraction of the hip, lower lumbar, and thorax muscles during the ride in cyclists having non-specific low back pain (NSLBP) and their normal counterparts with increasing time. A total of twenty-five cyclists participated in this study. Thirteen cyclists had NSLBP and they were differentiated from their 12 healthy without pain counterparts after assessment for low back pain. They were to ride their bicycle on a training roller for 30 min or till the back pain starts. Muscles kinematics was measured with the NORAXON™ USA monitoring system. Pain scale ratings were taken throughout the riding. Repeated measures ANOVA revealed a significant effect for the NSLBP group for thoracic erector spinae (TES) and multifidus (MF) $F(1) = 7.003$, $p \leq 0.024$ and $F(1) = 24.23$, $p \leq 0.001$ muscles respectively. The decrease in the mean amplitude of MF, TES could be due to impaired flexion relaxation response of putting strain on spinal structures leading to pain and non-pain group showing an increasing trend for the same variable may be due to strong compensatory mechanisms of fundamental stabilizers which co-contract with increased strength when muscles controlling movement previously start fatiguing. This study suggests that the NSLBP group shows a motor control pattern disturbance leading to decreased co-contraction of TES and MF may give pain.

Keywords Electromyography · Cyclists · Low back pain · Multifidus · Erector spinae

1 Introduction

Relatively few movements of the limbs come up with low back pain symptoms. However, sitting and leaning forward are two main contributing positions. Correcting these positions and motions can be intricate because they are part of many ADLs

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(activities of daily living). Mostly the spinal dysfunction is the result of impairments in positioning, stabilization, and biomechanical parameters of the spine. In the healthy spinal musculature principles of mechanics such as movement along the path of least resistance are followed by poised isometric contractions. More the segments, the greater the flexibility of the segments [1].

Cycling mostly deals with the activity of the legs and feet. However, for torso support firing of upper limb musculature is helpful equally. Greater than 30 min of cycling mainly followed by pain in the lower back [2] Similarly, cyclists already having NSCLBP had higher flexion of lumbar spine than age-matched subjects [3] overuse injuries are usually noticed in the cycling population. The study by Dettori and Norvell [4] provided support for the common occurrence of injuries to low back pain that was up to 75%. In parallel, another study stands as a pillar to the pathology of NSLBP which shows silence of erector spinae muscles has been related to the nonspecific low back pain [5] also classified as flexion pattern disorder. The plausibility of NSLBP [6] reported for cyclists was high and supposed to occur because of forwarding flexion of the torso along with marked lumbar convex curving on the bicycle rather during stance on foot [7]. Burnett [6] also studied kinematic patterns for cyclists and showed that there was no significant difference between the pelvic angle for cyclists with and without low back pain during cycling till pain started. There is a lack of study which addresses the role of specific muscle activation imbalances in cyclists having NSLBP as a possible primary causative factor. Further, EMG studies between low back pain and control groups in cycling are minimal. Thus, the present study is to assess the recruitment pattern of all the muscles supporting the lower lumbar region in both the control group and NSLBP groups of cyclists using the sEMG.

Flexion-Forward Bending

The mean lumbar range of motion was evaluated by Woolsey and Norton [3] which was 56.6°. The lumbar region must not go beyond half of its full range of motion during flexion before the flexion of the hips. Furthermore, after full flexion a flat lumbar region should be visible otherwise it is considered that lumbar musculature is malfunctioning. More movement of the lumbar spine than hips is noted during 30°–60° angle bent forward. Prior studies were conducted mostly on healthy riders or non-riders. In which Cyclists having anterior knee pain and NSCLBP were studied characterstics of cyclists having NSLBP have been noted prior and after the changed angle of saddle no study has yet reported about values for biomechanical parameters to have information before happening the injury. Muscle and recruitment pattern impairments are major biomechanical factors to cause injuries. The muscles of the anterior lumbar region may fire earlier than hip flexors for bending forward while seated on cycle holding handlebars. The hamstring and gluteus maximus muscles could be short. The back extensor muscles might be weaker, whereas the anterior lumbar muscles may be short and weak.

2 Methodology

2.1 Sample Design

- The design of the study is an observational study, with a sample size of 25.
- The effect size for the sample population taken in the study for comparison of pain group subjects throughout increasing time points was calculated by biostatistician, with the level of significance of 5%.
- A mixed population of National and International level Cyclists was selected.
- They were currently pursuing their training of road cycling for one hour daily in two slots for a day, in which they cycle for 30 min continuously on a heavy gear of 100–102, in the morning and for the same period in the evening in the main campus of Guru Nanak Dev University, Amritsar.
- The whole study procedure was carried out in the lab setting of the MYAS-GNDU Department of Sports Sciences and Medicine.

  Inclusion criteria:
- All the cyclists between the age of 18 to 28 having non-specific low back pain.
- NRS greater than (2/10) in GNDU, Amritsar.
- Cyclists without pain NRS less than (2/10) in GNDU, Amritsar.

  Exclusion criteria:
- Cyclists with any neuromuscular disorder.
- Cyclists having back pain due to known structural pathology.
- Segregation into pain and the non-pain group was done. There were 12 cyclists in the non-pain group. Their age was 20.40 $\pm$ 2.27 years, weight 66.00 $\pm$ 5.79 kg, and height 174.10 $\pm$ 5.56 cm. Pain group 13 cyclists mean age 21.6 $\pm$ 2.10 years, weight 70.50 $\pm$ 7.71 kg, height 173.58 $\pm$ 4.99 cm, having a previous history of low back pain were selected.
- *Low back pain and questionnaires*: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms for low back pain [8]. After the name registration, the interviewer went through questionnaires specifically asking about lower back pain.
- Cyclists with low back pain were assessed separately so that patients presenting symptoms of non-specific low back pain could be selected. NRS of pain group was taken and had a baseline NRS of 4.23 $\pm$ 1.30 in pain group and 1.58 $\pm$ 0.66 in non-pain. NRS score was taken over the time of 7 days before investigation.
- Subjects were instructed not to partake in any heavy training or physical activity 24 h before their clinical assessment or testing day. Ethical clearance for the study was provided by the Institutional ethics committee of GNDU and informed consent was obtained from subjects before testing (Table 1).

Table 1 Demographic data of pain and non-pain group

Demographic data	Non-pain		Pain	
	Mean	SD	Mean	SD
Age	20.40	±2.271	21.67	±2.10
Weight	66.00	±5.793	70.50	±7.71
Height	174.10	±5.567	173.58	±4.99

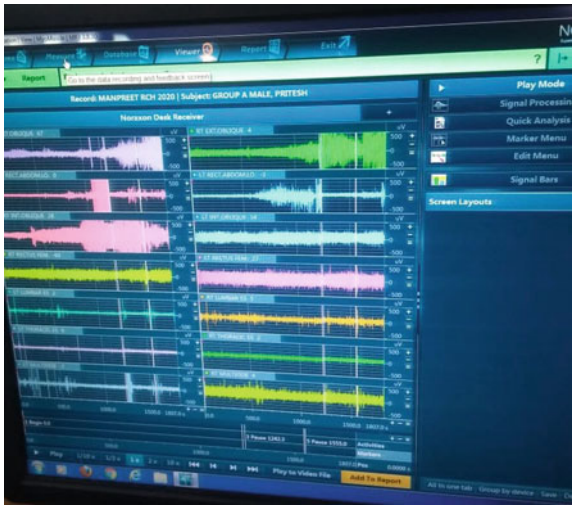

Fig.1 EMG amplitude recording of respective muscles

2.2 Data Collection

For the assessment of muscle activation the multi-model device Telemetry DTS EMG sensor system, NORAXON USA was used. MyoMUSCLE™ is the software module that has been used to process the EMG signal as shown in Fig. 1. Removal of hairs was done to reduce skin resistance and cleansing was done with an alcohol swab. EMG electrode impedance tester model NORAXON INC. USA was used to measure the impedance of skin. Silver chloride one use electrodes of (6 cm radius, 2 cm interelectrode distance), were attached to the exposed surface on the body along the direction of myofilaments. It was taken into consideration that riders feel free of any hindrance caused by wires nearby the receiving units and movable patient units were attached in isolation.

Tests for maximum voluntary isometric contraction were done before data collection started on the bicycle. A time limit of 10 s was kept to hold the contraction. For erector spinae muscles player was taken to the lying flat face facing the floor then instruction was given to lift off the table while one physiotherapist held the legs of the player, and the other applied downward force to resist that movement by the player.

To produce MVIC for muscle fibers of the anterior compartment of the lumbar spine mainly the rectus abdominis cyclist was asked to lie eyes watching the ceiling while physiotherapist holding legs straight. The cyclist was instructed to make a rise-up movement with resistance applied to the shoulder of the subject. Another test was performed in the same position but the rider was asked to try to reach ASIS of the opposite side with shoulder tip while resistance was being applied to shoulder and muscle tested was external oblique of the same shoulder which he was trying to touch the ASIS. For the internal oblique and the left external oblique, the same procedure was performed with the investigator standing at the right side applying resistance to the left shoulder for the left external oblique and right external oblique. For the erector spinae muscles subject laid prone position while maintaining the horizontal zero degrees position off the table for thoracic erector spinae (TES) thorax only was off the couch. For lumbar erector spinae (LES) lumbar region was also off the bed while legs were supported. For multifidus (MF) subjects in prone lying asked to lift arm and leg of the opposite side just above the surface of the couch. Quadriceps femoris (QF) was tested in prone lying while resisting to oppose the motion of knee flexion. MVIC for rectus femoris (RF) was taken while the subject was seated on a high table and resistance been given to oppose the knee extension. Root mean square window set on the machine was 150rms. This calculation approach for muscle activity has been proved of its trustworthiness for different types of subjects having non-specific low back pain and healthy controls [9].

Cyclists were asked to ride their cycle on an indoor wind trainer installed in the lab. While maintaining a Maximum heart rate at 75% and cadence of 100 -120 RPM. As Fig. 2 shows the experimental setup in EMG laboratory.

To reduce the time when pain arises subjects were instructed to stay seated on the seat during the whole ride. Pain group—total ride time was12.7 to 38.57 min) till the pain was no too great to be unbearable. For the non-pain group—the total ride time was12.3–53.57 min). as the subjects were age-matched so, mean differences would not be too great between the groups at different time points within the group. The NRS scores at the end of the ride for the pain group were 4.47–1.50. All the players are very active physically so no similarity could be kept and controlled on this basis of physical activity done per day. To assess synchronized trunk and abdominal muscle electromyography (EMG) was used and data were collected at the start of each ride and then every 5 min throughout the duration of the ride. investigated muscles in this study were three pairs of abdominal muscles and three pairs of back muscles two pairs of leg muscles, which are given as follows:- thoracic erector spinae, lumbar erector spinae, multifidus, rectus abdominis, external oblique, internal obliques, rectus femoris, biceps femoris.

3 Results

The Numeric Pain Rating Scale score result: Scores for pain perceived by the cyclists are listed in Table 2. Perceived distress on riding the bicycle in the musculature of the

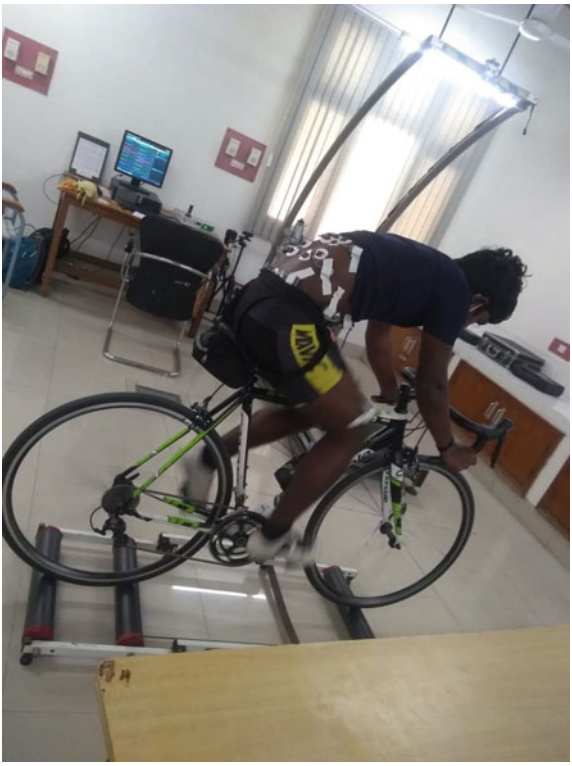

Fig.2 Experimental setup in EMG laboratory, MYAS GNDU department of sports sciences and medicine

Table 2 Difference in low back pain during different stages of the experiment

Low back pain	Pain group			Non-pain group		
	Mean	SD	P-value	Mean	SD	*P*-value
Baseline	4.41	±0.11	0.031	1.58	±0.66	0.193
Cycling	5.21	±0.17	0.047	1.41	±0.51	0.148
End	4.47	±0.11	0.032	1.50	±0.52	0.150

lower back group was significantly greater ($p < 0.05$) during cycling than in baseline and ending point. In addition to this mean for pain was also higher in the pain group than in the non-pain group.

In the maximum voluntary contraction study on cyclists, statistical test (ANOVA) significantly discerned ($p < 0.05$) during sEMG activity of pain group while riding a bicycle when compared to the non-pain group. Figure 1 shows the muscle fiber activation of MF, TES, LES. The slope of all three muscles switches from high to low throughout the period (baseline 0 s to 1800s) for the pain group but elevating for the non-pain group ($p < 0.05$)with increasing time. Effect size for multifidus = 0.41, $p \leq 0.02$, thoracic erector spinae = 0.71, $p \leq 0.002$ and lumbar erector spinae

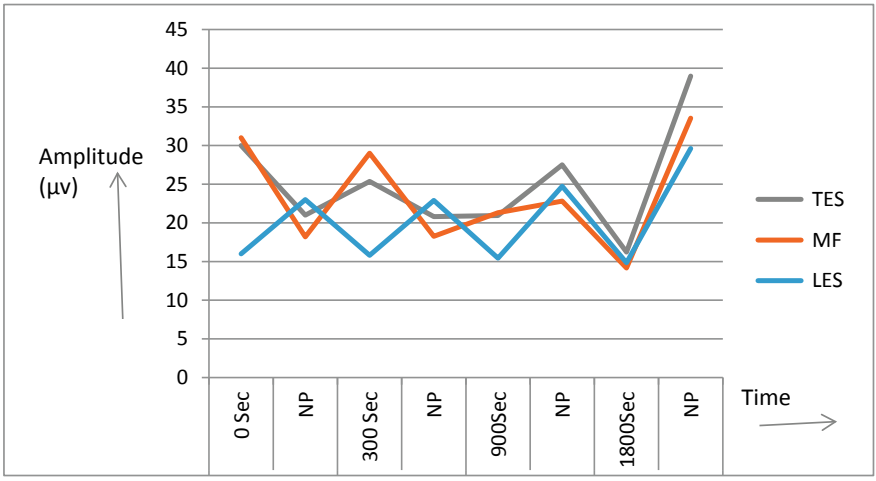

Fig. 3 Amplitude pattern of muscle activation with time

$= 0.82$, $p \leq 0.18$. Time-domain analysis indicated that the multifidus and thoracic erector spinae was significantly fatigued for the pain group (Fig. 3 and Table 3).

4 Discussion

This study was done to examine the change in muscle fibers firing in cyclists having NSCLBP and the healthy controls during incessant bike ride till the perceived pain goes beyond bearable range. Preferred design of the study was a two group observational study to define the pathway followed by the musculature of cyclists having back pain and those without it. It was important to maintain the group with similar participants in the pain group which was done by accurately assessing subjects having NSLBP and presenting pain clinically in the lower segment of the back. Secondly, special consideration to handlebars was given to make sure that both the groups place hands or arms on tri-bars or drop bars respectively while remaining seated as long as possible during the complete ride. The muscle activation during long-duration continuous is outlined in this segment. For this study muscle groups of anterior, dorsal, lateral region of abdomen and thigh muscles anterior and posterior were analyzed. The results of this study supported the alternate hypothesis.

Specifically, mean amplitude altered once during the bike ride kept altering and never reached the baseline level. which shows there was a continuous change in the firing rate of the myofibrils. As the muscle activation amplitude kept decreasing it discerns that the force production by muscle fibers is decreasing with time furthermore musculature of the dorsal lumbar region works concentrically and isometrically to hold the lumbar spine in place and maintain stability without pain during activity,

Table 3 Responses (number of riders) to standardised nordic questionnaires for the analysis of musculoskeletal symptoms for low back pain

Symptoms ever	13
Symptoms in previous 12 months	13
Total symptom duration	
1–7 days	5
8–30 days	7
More than 30 days but not daily	3
Daily	1
Outpatient medical assistance	9
NSAIDs in previous 12 months	3
Hospitalization	0
Surgery	1
Missed training in previous 12 months	5
Number of days of missed training	
1–7 days	3
8–30 days	1
More than 30 days	1
Missed races in previous 12 months	1
Number of missed competitions	
1–3 races	3
4–10 races	0
More than 10 races	1
Referral of symptoms	
Gluteal region	2
Thigh	2
Knee	0
Lower leg or foot	0

but subjects who have pain in back shows decreased mean amplitudes hence, adopted muscle lengthening during cycle riding for the continuous-time period is causing the symptoms.

EMG activation analysis Flexion relaxation (FR), a myoelectrical switching down the response of lumbar and thoracic extensor muscle at the almost completion level of lumbar flexion. Still, the lumbar flexion angle on its own is not enough to illustrate the pathway that curbs FR. So, FR may lead to improper alignment of the vertebras due to the effect of gravity which can lead to back pain progressing to the whole kinematic chain [10]. The synchronizations for lumbopelvic movement are dissimilar between the healthy population and subjects allocated in two particular cycling subgroups. Hence flexion relaxation phenomenon of erector spinae muscle is impaired [11]. The current study also identifies that decreased activation of erector spinae muscles resulted to forward bending and altered the position of the back and torso. This is

in significance to the null hypothesis that the muscle activation decreases with time during continuous riding of the cycle in the pain group but the same amplitude or increased activation is seen, which may be due to the compensatory effect of other muscles in that region.

In contrast, the mean amplitude of muscle contraction did not rise or remained the same after decreasing once. It was concluded in a study [6] that cycling individuals distressed due to low back pain tended forfeiture of activations of muscle fibers of multifidus alone. This muscle is acclaimed to be a fundamental intervertebral support to prevent anterior translation of vertebras during a variety of alterations in the position of the lumbar spine. But in this study, a loss of co-contraction of the erector spinae muscle is also observed in previous study [12] it has been also found that during plank and isometric extension of spine slumping of the amplitude of antagonist dynamic supporters could suggest decreased firmness of the back extensor in the lumbar region giving pain in the lower back. The findings suggest altered motor control of both multifidus as well as erector spinae has a role in the development of LBP in cyclists. The LM (lumbar multifidus) has been proved previously to be the main supporter of the lumbar spine and wasting of the erector spinae that hinders capability to maintain the spine in the unbiased phase and is sturdily concomitant with NSLBP [13]. Another study supports the results of the current study which concluded that improper function of the LM could cause the LBP with a loss of synchronization of muscle fiber activation [14].

The cycle riders in the pain group had been shown to exhibit larger disproportionateness in superficial LM during the start and at the finishing stage of the ride in comparison to the non-pain cycle riders group.

5 Conclusions

This study concluded that cyclists with NSLBP show a decreasing trend in muscle activation of the multifidus as well as erector spinae. Both the muscles are liable to cause impaired alignment of the trunk while cyclist for longer durations and leads to low back pain. However, more studies should be performed with a larger sample size and the results of the current study should be viewed carefully because of the medium level of sample size. Our study goes in line with previous studies which identified that there was underlying movement control impairment that biases the cyclists towards flexion strain of the lumbar musculature. Further research into this group with larger sample size is required to establish rehabilitation strategies for treating NSLBP cycle riders.

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An Ergonomic Study on Prevalence of Work-Related Musculoskeletal Discomfort Among Information Technology (IT) Professionals Working from Home in COVID-19 Pandemic

Jigisha Patel and Tirthankar Ghosh

Abstract COVID-19 Pandemic made working from home a necessity for IT professionals and computer users. Prolong working hours in confined or awkward posture leads to musculoskeletal injuries. The aim of the present study was to assess the prevalence of work-related Musculoskeletal disorders (MSDS) and ergonomic limitations of computer users from IT background working from home due to the COVID-19 Pandemic. Eighteen subjects from IT Industry between 25 and 35 years were randomly selected for this study. A Workstation checklist and a Modified Nordic Questionnaire was used to assess the present workplace at home and prevalence of discomfort or pain. The postural analysis was performed using the standardised protocol of Rapid upper limb assessment (RULA). The study indicated that IT professionals working from home had an increased likelihood of developing work-related musculoskeletal injury primarily in neck, Shoulder, wrist, elbow and lower back. About 49% of the subjects were respondent to discomfort or pain. 28% of the subject felt moderate low back pain and 44% experienced mild low back pain, 50% were having neck discomfort and 44% underwent both. RULA scores of IT professionals indicated the risk of development of musculoskeletal injury. IT was also revealed that 65% of the subjects were unaware of work ergonomics and 17% of subjects followed work ergonomics. It may be concluded that lower back discomfort and pain in upper extremities are the major health issues, occurred prevalently among the IT professional during working from home without an ergonomic workplace during COVID 19.

Keywords IT professional · Ergonomics · MSDS · Work from home · COVID 19

1 Introduction

The COVID-19 Pandemic brought enormous changes in lifestyle and work cultures across the globes. New terminologies of work like “work from home”, “Remote

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working" "Mobile working" were been introduced to deduce the physical contact among people and to curb the graph of the rate of infection and mortality rate [1, 2]. Work from home allows you to continue your job without restricting to any defined work place with all the possible technology requirements. The lock-down lead to complete shutdown of school, colleges, organised and unorganised sector. It brought new working from home guidelines and teleworking accessibility to professional and technical services as Law firms, accounting firms, Advertising agencies and consultancies, IT sector and Educational Institutions [3]. In India the pandemic increased work from home culture in corporate majorly IT companies, software companies dealing majorly with computer use [2]. Studies showed remote working gave the perks of reduction in commuting, increased productivity, increased employee motivation, better work-life balance and work schedule flexibility [4, 5]. However according to a survey, the negative aspects of work from home in India mentioned 81% felt increased office workload. 60% were unable to differentiate between home and working hours. About 48% were interrupted by family members being present around leading to affect concentration [6]. Working at home do have many drawback including the inaccessibility of correct ergonomic workplace limiting the practice of having good posture while working and leading to development of musculoskeletal disorders (MSDs) [7, 8]. MSDs are observed in every kind of industries and occupation. IT Industry being one of them demanding majorly computer usage and sedentary position for prolong hours. Working for prolong hours in static position increase the risk of developing neck pain and Low back pain [9]. Some study suggest the association of poor posture while working for long hours in VDT causes various health disorders which includes fatigue and other musculoskeletal disorders (MSDs) [10]. Studies have found that the portable gadgets i.e. laptop, iPads, tablets, mobile phones have been a preference over desktop allowing users to have a range of comfortable position to work from sitting straight on chair, slouching in sofa to lying in bed while working [11–13]. Studies have highlighted the increased risk of work-related musculoskeletal disorders (wMSDs) with the use of personal computers [14–16]. There are many risk factors for the occurrence of MSDs among which static workload and workstation factors are noted ones [17–19]. The major affected areas in wMSDs are shoulder, arms, elbow, wrist, hands, back, legs and feet. Studies report more than 81% of the keyboard user suffer from various musculoskeletal disorders (MSDs) [16]. Technological advancement and mechanical modification leads to the increased incidence of MSDs. The main aim of the present study was to assess the prevalence of work-related MSDS and ergonomic limitations of computer users from IT background working from home due to the COVID-19 Pandemic.

2 Material and Methods

Selection of the subjects: The study was carried out on computer users from IT background who are working from home in the COVID-19 Pandemic. Eighteen computer users were selected by randomly for the study. All the selected subjects

were working from home from past 6 months and were in the age group of 25–35 years. Consent of the subjects was taken verbally before the questionnaire was sent for the further proceeding of our online survey.

2.1 Questionnaire Study

A Modified Nordic Questionnaire was used for understanding the body discomfort and pain among the IT Professional selected for the study. It comprised of the multiple-choice questions with multiple–choice responses. The questions were categorised into the major sections concerning subjective symptoms of musculoskeletal system or work-related pain implying discomfort in any part of the body and if felt any discomfort then which are the areas dealing with—neck, shoulder, elbow, wrist, hand, upper back, lower back, hip, knee, and ankle and the other reported associated disabilities. The questionnaire was used to evaluate the prevalence of musculoskeletal disorders (MSDs) risk in the selected subjects. The questionnaire was sent through email, and they have replied back in it.

2.2 Workstation Assessment

The home workspace of the IT professional was assessed by gathering the information of adjustability, desk, monitor height, distance and tilt, ergonomic work habits—what kind of work set up used, what kind of sitting postures practiced while working, possible areas of home accessed for working, what kind of work set up used, do you practice taking hands free call while working, do you stand up while taking calls, do you take stretch break during the working hours, do you take eye break, frequency of taking breaks.

2.3 Analysis of Working Posture

RULA technique was used here to assess the postural discomfort of the IT professional, work from home adopted posture. This was carried out with the aid of digital photography. Later on, stick diagrams were drawn from still photo and analysed by ErgoFellow 3.0 Ergonomics software developed by FBF Sistemas, Belo Horizonte, Brazil.

2.4 Statistical Analysis

A one tail chi square test of independence was performed to find out whether or not there is any significant association of working hours with discomfort feeling in subjects for the chosen level of significance ($P < 0.05$).

3 Results

Table 1 represents the demographic information of IT professionals showing the mean age of the subjects 28 years with average height of 165.8 cm and 67.8 kg weight respectively.

It was found that the minimum working hours were 6 h and maximum were 11 h. On the basis of the findings the daily working hours of the subjects were categorised into 3 groups respectively—6 h, 6–9 h and > 9 h. It was found that 39% of IT professional felt discomfort while working for 7–9 h, 5% felt discomfort working in 4–6 h and 5% felt discomfort while working >9 h, as shown in Fig. 1. Table 2 represents IT professional working between 7 and 9 h were the maximum. On continuing working in the current workspace set up it was found that the participant felt discomfort in different areas of body of which maximum discomfort was felt in lower back (20%) shown in Fig. 2.

It was found that there are various areas of the home accessed for work which were segregated as office table/study table/laptop table /office chair, dining table, bed, sofa and all 4 of them. The frequency distributions of the IT professionals using

Table 1 Demographic information about the IT professionals

Parameters	IT professionals
Age (years)	28.3 (±12.95)
Height (cm)	165.8 (±15.90)
Weight (kg)	67.8 (±16.09)

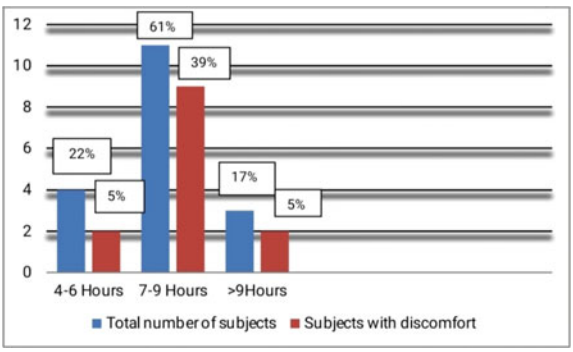

Fig. 1 Graphical representation of IT professional with discomfort

Table 2 Duration of working hours and prevalence of discomfort (pain) among IT professional

Duration of work (hours)	Total number of subjects	Subjects with discomfort	chi square value
4–6 h	4	1	2.1515 not significant ($P < 05$)
7–9 h	11	7	
>9 h	3	1	

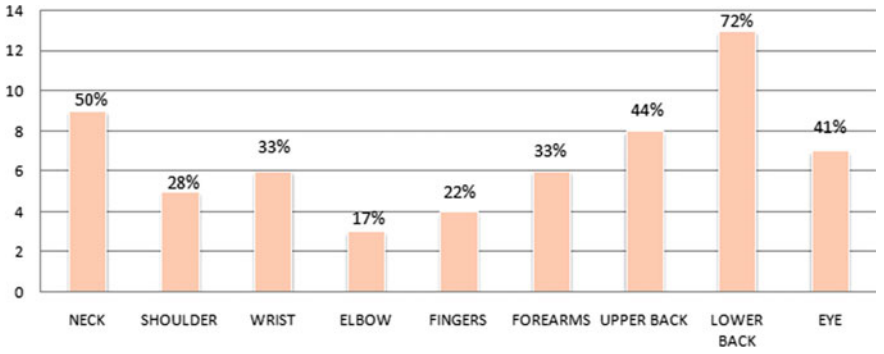

Fig. 2 Frequency distribution of discomfort in different parts of body

the different categories of the home area are tabulated in Table 3. It is seen that 39% of the population used office chair and table or study table set up, 11% accessed only dining table, 11% used bed, 6% used sofa and 33% used all of them respectively shown in Fig. 3.

It was found that only 17% of the participants were aware of the workplace ergonomics and followed the workplace ergonomic recommendations while 18% were not sure of the correct work ergonomics as shown in Fig. 4.

The response of the participants about the work equipment's considered – chair adjustability and inclination characteristics, distance, height and tilt of the monitor, lighting for reading and writing document, headset use for hands free call and use of laptop stand, external keyboard and mouse for laptop were taken in counts and the frequency distribution is shown in Table 3.

The data of the responses for following the correct workplace ergonomic habits were collected and it was found that 68% of the participants do not mobilise and switch their posture between sitting and standing during working hours, 72% do not stand up while taking calls, 56% do not take stretch breaks during working day, 72% do not take eye break respectively shown in Table 4.

Table 3 Equipment's frequency percentage of home computer workstation ergonomics

Equipment	Response	Frequency (N = 18)
Chair		
Adjustable seat height	YES	10(56%)
	NO	8(44%)
Adjustable lower back support	YES	8(44%)
	NO	10(56%)
Adjustable armrest	YES	10(56%)
	NO	8(44%)
Adjustable inclination	YES	7(41%)
	NO	10(59%)
Monitor		
Top of the monitor set at eye level	YES	9(50%)
	NO	9(50%)
Monitor at arm length away	YES	10(56%)
	NO	8(44%)
Monitor and work surface free from glare	YES	14(78%)
	NO	4(22%)
Lighting		
Appropriate lighting for reading/writing	YES	15(83%)
	NO	3(17%)
Telephone headset for hands free call	YES	11(61%)
	NO	7(39%)
Laptop		
Laptop stand	YES	7(39%)
	NO	11(61%)
External mouse and keyboard	YES	8(44%)
	NO	10(56%)

The discomfort in different part of body in IT professionals was collaborated with the different workplace setup used by them to look for the risk of MSD with RULA score shown in Table 5. It was found that most of the postures adapted by IT professionals - slouching while working in dining table (56%), slouching while working on bed without using the head board or backrest (50%) were awkward and involved medium risk of developing MSD requiring further investigation and

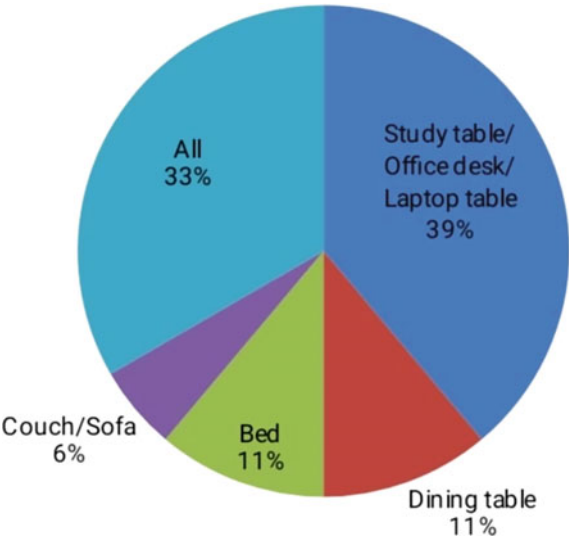

Fig. 3 Workplace distribution while working from home

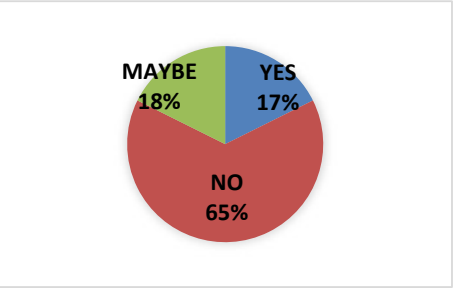

Fig. 4 Frequency distribution of awareness of workspace ergonomics

Table 4 Ergonomic habits frequency distribution

Ergonomic habits	Response	Percentage
Sit with back straight, feet flat on the floor or a footrest and shoulder squared	YES	13(72%)
	NO	5(28%)
Switching between sitting and standing working position throughout the day	YES	6(33%)
	NO	12(67%)
Standing while taking up calls	YES	5(28%)
	NO	13(72%)
Stretch breaks during the workday	YES	8(44%)
	NO	10(56%)
Eye breaks	YES	5(28%)
	NO	13(72%)

Table 5 Analysis of the sitting posture of the IT professionals

Work place	Posture	Work posture	Frequency (n = 8)	RULA score	MSD rick
Office chair		Sitting straight with back supported by back rest	14 (78%)	2	Negligible risk no action required
Office chair		Slouching/sitting without using the backrest	13 (72%)	4	Low risk, change may be needed
Dining chair		Sitting straight with back supported by back rest	8 (44%)	3	Low risk, change may be needed
Dining chair		Slouching/sitting without using the back rest	10 (56%)	5	Medium risk, further investigation
Bed		Seated with using headboard/pillows as back rest	10 (56%)	3	Low risk, change may be needed
Bed		Slouching/seated without using the headboard/pillow	9 (50%)	5	Medium risk, further investigation
Sofa		Sitting straight with laptop on lap	7 (39%)	3	Low risk, change may be needed
Sofa		Slouching with laptop on lap	9 (50%)	4	Low risk, change may be needed

requirement of changes. Slouching while working in office chair (72%), sofa (50%) involved low risk.

4 Discussion

From the current study it has been observed that IT professionals are forced to adjust with their household non- ergonomic furniture for their office work. It is been seen in the Table 2 and Fig. 1 that the IT professionals are exposed to different working hours categorised in 4–6 h, 7–9 h and >9 h respectively. From the Fig. 1 it was found about 49% of the IT population working in different working hours experience discomfort feeling in different parts of the body. However it was seen there was not significant association of working hours with the occurrence of discomfort feeling among the IT subjects. It was seen from the Fig. 2, the IT professionals stating their discomfort in various part of the body out of which had 41% eye, neck 50%, shoulder28%, forearm 33%, elbow 17%, wrist 33%, fingers 22%, upper back 44% and

lower back 72% respectively. This could be due to awkward postural adaptation while working for prolong hours which increases the risk for developing musculoskeletal disorders (MSDs). The probability is supported by the studies of various researchers prolong working hours in awkward and static postures lead to the development of musculoskeletal Diseases (MSDs) [20–23]. In the current study it was found that IT professionals access different areas of home and use home furniture as shown in Fig. 3. Robertson et al. in their study showed significant reduction in musculoskeletal risk after training in working in the flexible workstation equipped with ergonomic features. Another study showed improvement in the body postures after training with working in ergonomic chair [24, 25]. Correct workspace ergonomics boost healthy and pain free working culture for employees by encouraging good posture, less exertion and fatigue, decreasing repetitive motion which leads to decreased risk of MSDs and enhanced productivity. Geetha Suresh mentioned in her study that use of proper workspace and correct ergonomic guidelines for computer users working from home can prevent MSDs and postural pain in future [26]. In Fig. 4 it is seen 65% of the respondents were having a lack of knowledge about the workspace ergonomic guidelines. Hence the respondents are not able to understand the correct ergonomics. They are compromising with non home furniture devoid of ergonomic characteristics and are forced to adapt the awkward and poor postures leading to various postural discomforts. The Health and Safety work report of Great Britain in 2019 by Health and Safety executive reported 40% of the MSDs were related to back with awkward body positions, keyboard work (desk sitting), repetitive movements being the major cause [27]. In the Table 3 we found 56% used chair devoid of adjustable back rest. As the chairs do not avail low back support, it may lead to low back pain (LBP). The results can be supported by the studies of Van Niekerk et al. showed some subjects using built in lumber support in "Ergonomic Chairs" had reduced back pain [28]. The laboratory research of Professor Grandjean showed backrest following the back shape of a human body relaxes the back muscle and works as lumber support when the workers is leaning in natural position [29]. In the present study 50% of IT professionals had not positioned the monitor at eye level and 61% of the laptop users do not use laptop stand for alleviating the height leading to development of neck pain in 50%. Snyder et al. showed the average neck strength with respect to neck angle is at 30° neck inclination [30]. It is also seen from a study that too low work surface not only leads the person to lean forward but also lower and rotate the shoulder forward resulting pain and fatigue in the levator scapular muscles. Jorgensen in his study showed the capability of the men to maintain 20° (forward) bending posture as there is increment of load-moment for each degree of back inclination above 20° [31]. In the observation and analysis of some of the posture of IT professional, it is found that they work for a prolong period with neck inclination 24° and back inclination 30°. Posture adoption involving extended head or neck for longer duration may increase the likelihood of musculoskeletal discomfort [32]. It is found from Table 4 the respondent do not change their postures from sitting to standing while working. Prolong sitting without intermittent postural breaks may lead to LBP. This can be supported by the study of Wong AY et al. recommended to move every 20 min to reduce the likelihood of developing LBP by prolong sitting [33]. Several studies

have shown an significant association between MSDs and breaks between working [34–36]. It was also found 72% do not take eye breaks while working which may lead to visual stress/discomfort. Sheddy in his study reported 50–90% of the computers users had experienced computer vision syndrome symptoms [37]. From the RULA assessment we found the RULA score of most of the posture adapted by the IT professional being 3, 4 and 5 which fall under low and medium risk zone of MSDs shown in Table 5. All the studied postures were not correct or linear definitely needs further investigation and changes. As they are not yet experiencing the alarming pain leading them to continue working in awkward postures. But the continuation may lead the IT professional to get severe MSDs in near future. Not only the continuation of posture involved with low or medium risk but also prolong working hours may be a cumulative factor for amplifying the probability of severe MSDs.

5 Conclusion

From the results and analysis of the study it can be concluded that 49% of IT professionals are working in awkward postures which increases the risk of MSDs majorly affecting the lower back. It can be attributed due to inaccessibility of ergonomic chair with backrest and height adjustability, failing to retain the neutral curvature of the spinal cord increasing while sitting leads to the development of LBP. Prolong sitting in a static, confined and awkward position for prolong period without taking intermittent breaks increase discomfort and pain perception in lower back, neck and eye respectively directing to work-related upper body MSDs. Improper positioning of monitor and using laptop without laptop stand can alleviate neck pain. Since the COVID-19 Pandemic has brought new normality which is happening to stay with us for a longer period. This brings into the necessity of upgrading present working from scenario for the IT professionals. Implementation of workspace with ergonomic equipments is the iota of decreasing the severity of MSD risks. Use of chairs with adjustable armrest, back rest, height and inclination, laptop with monitor stands and footrest can lead to the reduce the risk of MSDs development. However conventional low paid comfort can be obtained by using pillows for backrest, stack of books for alleviating height of the monitor, attachable armrest to adapt good posture while working with computing devices. It is recommended to follow correct ergonomic work habits of taking eye breaks in every 20 min as per 20-20-20 rule and taking intermittent breaks in every 30 min to reduce MSD risk, inefficiency in work and fatigue. Regular meditating, working-out, yoga and right amount rest coupled with ergonomic workspace can lead to improved physical and mental health increasing productivity.

Limitations of the study: As the study was conducted right after the lockdown, the IT professionals immediately had to start work from home. They might have not get time to acclimatize with the new mode of working system. So there lies a future

scope of continuing the study, the differentiation of acute and chronic effect of work from home if the workers continue working from home.

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Prevalence of Musculoskeletal Discomfort Among Banking Employees in Assam, India

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Abstract Banking sector act as spine for nation's economy. Rapid changes in technology and computerization process in the banking sector might not affect only employees but also their working environment. Poor work station design, continuous use of computer for the entire workday, prolong sitting, awkward posture and long periods of static work may affect the health of bank employees and predispose them to musculoskeletal problems. Objective: To identify the musculoskeletal discomforts experienced by the employees working in three district of Assam namely Guwahati, Jorhat and Sivasagar. The selected sampling technique was purposive convenience sampling. Online questionnaire was used as a tool for data collection which had two sections. The first section comprised of background information of the employees and the second section covered Standardized Nordic Musculoskeletal Disorder Questionnaire (NMQ), 1987. The findings revealed that mean age of the respondents was 32.88 years. More than two-third of the respondents were males having 1–12 years of service in banking sector. Majority of the respondents perceived discomfort in their neck (64.42%), right shoulders (44.23%) and upper back (52.88%) during last 12 months. It was also unveiled that discomfort in right wrist was perceived by 44.23% of the respondents during last 12 months. The findings of the study will be helpful for the banking sector and designing the workplace as per the employees for better productivity and efficiency.

Keywords Musculoskeletal disorders · Banking employees · Assam

1 Introduction

Banking is the lifeline of the nation and its people. Banking has aided in the development of key economic sectors of the country. The efficiency and growth of a nation depend on the strength and efficiency of its financial institutions [1]. Banks are fundamentally human organizations that require human skill, time, and effort in order to

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achieve their goals of increasing profits and wealth through satisfying customer. Employees with favourable work attitudes, strong commitment, and high morale are likely to provide better customer service [2]. So, it is necessary for the employees to function effectively for consumer satisfaction as well as economic development of the nation. Health of the employees is the determining factor for workplace productivity. Good health motivates employees and also reduces absenteeism, increase engagement and improve productivity.

The growing automation and computerization process within bank work implied changes in organization working conditions and relationships [3]. Both bank employees and their working environments have been impacted by technological advancements, particularly the use of electronic data and equipment. More people are completing their work using visual display terminals such as computer and related equipments [4]. Electronic data is primarily displayed on visual display terminals; however, awkward body posture and prolonged sitting in front of these terminals can cause a variety of health problems, including eye strain, muscle fatigue, and other musculoskeletal discomforts [5].

As early as the beginning of the eighteenth century, musculoskeletal discomforts were recognized as having occupational etiologic factors as early as the beginning of the eighteenth century. The musculoskeletal discomfort refers to the pain in muscles, ligaments and tendons, as well as pain throughout the body. The discomfort can range from minor to severe, interfering with daily activities. Acute pain is defined as pain that occurs suddenly and lasts for a brief period of time. Chronic pain is defined as pain that last for more than three to six months [6]. Moreover, people who experiences these discomforts suffer mentally and physically and are faced with the possibility of permanent, partial or total disability [7]. Experiencing these discomforts in different parts of the body for a longer period of time may lead to musculoskeletal disorder [8].

Musculoskeletal discomforts have been identified as one of the primary causes of burnout in bank employees. The use of computer for data collection, processing and programming is common in the banking industry, which increases the risk of acquiring musculoskeletal problems [9]. Bank managers are in charge of planning and defining goals for local branches, as well as monitoring progress, making decisions and attending special clients. These tasks are completed in daily 8–10 h shifts using personal computers and telephone. The majority of the time, the managers' job entails sitting. The duties of cashier include dealing with deposits and withdrawals, receiving a variety of payments, and selling branch products for clients. These duties are completed while the employee sits for their 8 h shifts, which include intensive usage of personal computers for data entry and the stamping of numerous documents [10]. The intensive computer work necessitates not only repetitive movements of the upper limbs, such as typing with the keyboard and manipulating the mouse, but also static muscular activity while maintaining a stable position for the arms and neck. The neck, shoulder, and upper limb muscles and joints are also overworked by computer activity in order to keep them in a static position. As the support structures for muscles and joints deteriorate, they become strained. The danger of ischemic damage increases as the tissue is stressed on a regular basis [11].

Despite technological advancements and mechanical workplace modifications, of working place, the incidence of MSDs is on the rise, which has a negative impact on both individual and the society [12].

Although several studies have been conducted on musculoskeletal discomforts among bank employees in other states of India and abroad, the actual nature and prevalence of this serious health issue in Assam has never been investigated. This study was designed to fill the knowledge gap in this area.

1.1 Objective

To identify the Musculoskeletal Discomfort experienced by the employees working in bank in Assam.

1.2 Hypotheses

The Musculoskeletal Discomfort experienced by the respondents during last 12 months will vary with their Personal Variables (Age in years, Gender, Working Experience in years) and their Situational Variable (Number of Working Hours).

2 Methodology

The study was conducted in order to investigate the prevalence of musculoskeletal discomfort among banking employees in Assam, India. Hence, the researcher adopted the descriptive research design for the study. After taking an informed consent from the bank managers, the data was collected from 104 respondents who were working as bank employee for minimum 1 year in nationalized and private banks of selected three districts i.e., Sivasagar, Jorhat and Guwahati of Assam, India. The survey was conducted on the basis of purposive convenience sampling. Online questionnaire was used as a tool for data collection which had two sections. The first section comprised of background information of the employees and the second section covered Standardized Nordic Musculoskeletal Disorder Questionnaire (NMQ) [15]. The collected data have been analyzed and interpreted using statistical tools such as frequencies, percentage, mean and standard deviation. Analysis of Variance (ANOVA) and t-test were applied to test the hypotheses postulated for the study.

3 Results and Discussion

3.1 Background Information

The age of the respondents ranged between 24 to above 44 years where mean age of the respondents was 32.88 years. 58.65% of the respondents belonged to age group of 24 to 33 years. 70.19% of the respondents were males. 52.88% of the respondents were married. It was found that majority of the respondents had 1–12 years of service in banking sector (88.46%). The data elicited that all the respondents were full-time permanent employee. It was found that majority of the respondents had 6 working days in a week (93.27%). The data also highlighted that slightly less than three-fourth (74.03%) of the respondents working hours were 5–6 h per day. The data also revealed that 52.88% of the respondents worked overtime for 2–4 h per week. On analyzing the data, it was observed that 76.92% of the respondents had one break in a day. The data also depicted that majority of the respondents had 21–40 min break in a day (82.69%).

3.2 Musculoskeletal Discomfort Experienced by Bank Employees

It was found that less than 64.42% of the respondents experienced musculoskeletal discomfort in their neck, more 52.88% of the respondents perceived musculoskeletal discomfort in upper back, 52.88% of the respondents experienced musculoskeletal discomfort in their lower back and it was observed that 44.23% of the respondents experienced musculoskeletal discomforts in their right shoulder and right wrist during last 12 month (Table 1 and Figs. 1 and 2).

The data in Table 2, revealed that less than one-half (48.08%) of the respondents experienced musculoskeletal discomfort in their neck and the data also revealed that more than one-third of the respondents experienced musculoskeletal discomfort in their upper back and one-fourth (26.92%) of the respondents experienced musculoskeletal discomfort in their lower back during last 7 days.

The data illustrated in Table 3 revealed that 26.92% of the respondents experienced discomfort in their neck, 16.35% of the respondents experienced musculoskeletal discomforts in their right shoulder and lower back and 15.38% of the respondents experienced musculoskeletal discomforts in their upper back during last 12 months which prevented them from carrying out their normal activities (job, housework, hobbies).

Table 1 Musculoskeletal Discomforts experienced by the respondents in their body parts as perceived by them during the last 12 months (n = 104)

Sr. No.	Body parts	Musculoskeletal Discomforts during last 12 months			
		Yes		No	
		f	%	f	%
1	Neck	67	64.42	37	35.58
2	Right shoulder	46	44.23	58	55.77
	Left shoulder	42	40.38	62	59.62
3	Right elbow	11	10.58	93	89.42
	Left elbow	6	5.77	98	94.23
4	Right wrist	46	44.23	58	55.77
	Left wrist	29	27.88	75	72.12
5	Right hand	44	42.31	60	57.69
	Left hand	31	29.81	73	70.19
6	Upper back	55	52.88	49	47.12
	Lower back	55	52.88	49	47.12
7	Right hip	14	13.46	90	86.54
	Left hip	12	11.54	92	88.46
8	Right buttock	12	11.54	92	88.46
	Left buttock	12	11.54	92	88.46
9	Right thigh	10	9.62	94	90.38
	Left thigh	10	9.62	94	90.38
10	Right knee	9	8.65	95	91.35
	Left knee	9	8.65	95	91.35
11	Right ankle	7	6.73	97	93.27
	Left ankle	7	6.73	97	93.27
12	Right feet	9	8.65	95	91.35
	Left feet	9	8.65	95	91.35

3.3 Testing of Hypothesis

The computed F–value for Personal Variables [Age (in years.), Working Experience (in years.) and their Situational Variable [Number of Working Hours] was found to be not significant. Thus, it can be concluded that Musculoskeletal Discomforts experienced by the respondents does not vary with the Personal Variables [Age (in years.), Working Experience (in years.) and their Situational Variable [Number of Working Hours]. Hence the null hypothesis HO1.1 was accepted.

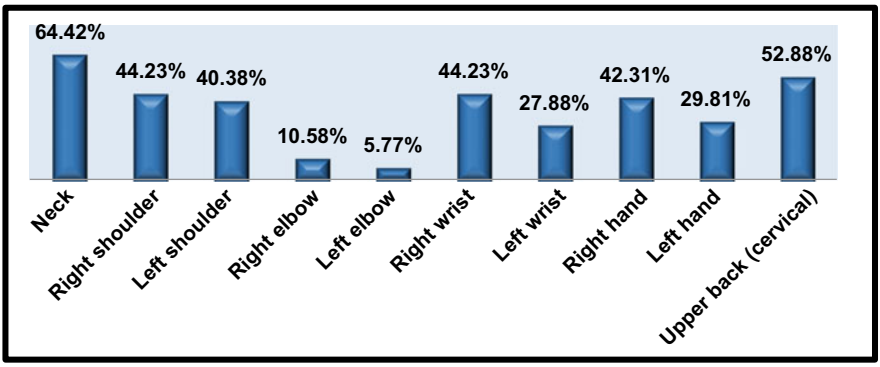

Fig. 1 Musculoskeletal Discomforts experienced in upper body parts during last 12 months (n = 104)

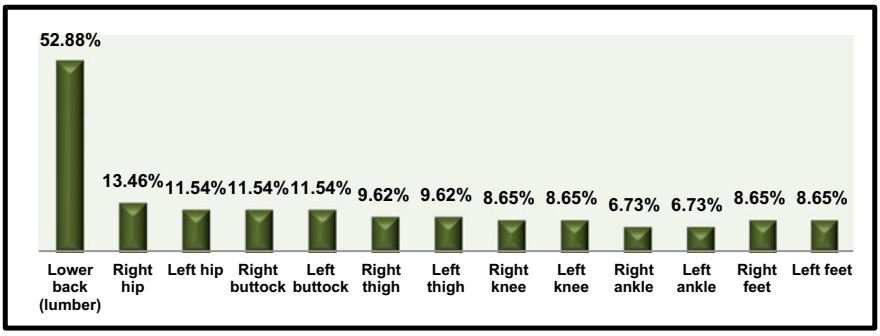

Fig. 2 Musculoskeletal Discomforts experienced in lower body parts during last 12 months (n = 104)

The computed t–value for Personal Variable (Gender) was found to be not significant. Thus, it can be concluded that Musculoskeletal Discomfort experienced by the respondents does not vary with Gender. Hence the null hypothesis HO2.1 was accepted.

Table 2 Musculoskeletal Discomforts experienced in their body during 7 days (n = 104)

Sr. No.	Body parts	Musculoskeletal Discomforts during 7 days			
		Yes		No	
		f	%	f	%
1	Neck	50	48.08	54	51.92
2	Right shoulder	26	25	78	75
	Left shoulder	14	13.46	90	86.54
3	Right elbow	9	8.65	95	91.35
	Left elbow	3	2.88	101	97.12
4	Right wrist	17	16.35	87	83.65
	Left wrist	7	6.73	97	93.27
5	Right hand	17	16.35	87	83.65
	Left hand	9	8.65	95	91.35
6	Upper back	36	34.62	68	65.38
	Lower back	28	26.92	76	73.08
7	Right hip	8	7.69	96	92.31
	Left hip	7	6.73	97	93.27
8	Right buttock	9	8.65	95	91.35
	Left buttock	7	6.73	97	93.27
9	Right thigh	6	5.77	98	94.23
	Left thigh	5	4.81	99	95.19
10	Right knee	3	2.88	101	97.12
	Left knee	4	3.85	100	96.15
11	Right ankle	3	2.88	101	97.12
	Left ankle	2	1.92	102	98.08
12	Right feet	7	6.73	97	93.27
	Left feet	5	4.81	99	95.19

Table 3 Frequency and percentage distribution of respondents according to their musculoskeletal discomforts in body parts that prevented the bank employees from carrying out their normal activities during last 12 months (n = 104)

Sr. No.	Body parts	Musculoskeletal Discomforts during last 12 months that prevented from carrying out normal activities			
		Yes		No	
		f	%	f	%
1	Neck	28	26.92	76	73.08
2	Right shoulder	17	16.35	87	83.65
	Left shoulder	11	10.58	93	89.42
3	Right elbow	2	1.92	102	98.08
	Left elbow	1	0.96	103	99.04
4	Right wrist	8	7.69	96	92.31
	Left wrist	3	2.88	101	97.12
5	Right hand	7	6.73	97	93.27
	Left hand	2	1.92	102	98.08
6	Upper back	16	15.38	88	84.62
	Lower back	17	16.35	87	83.65
7	Right hip	3	2.88	101	97.12
	Left hip	1	0.96	103	99.04
8	Right buttock	2	1.92	102	98.08
	Left buttock	1	0.96	103	99.04
9	Right thigh	1	0.96	103	99.04
	Left thigh	0	0.00	104	100
10	Right knee	3	2.88	101	97.12
	Left knee	1	0.96	103	99.04
11	Right ankle	3	2.88	101	97.12
	Left ankle	0	0.00	104	100
12	Right feet	2	1.92	102	98.08
	Left feet	0	0.00	104	100

4 Conclusion

The result of the study concluded that the tasks performed by the bank employees posses moderate risk of occurrence of musculoskeletal discomfort and the commonest site of pain being the neck, upper back, lower back, right shoulder and right wrist. Factors responsible for disability as well as risk factors includes repetitive use of computer, Individual factors, prolonged awkward postures, job stress, lack of adequate leisure time and extra working hours. From this study we concluded that the tasks performed by the bankers posses moderate risk of occurrence of musculoskeletal injury.

The information gathered through the present research would be beneficial to the students to gain insight into the area of ergonomics on work-related musculoskeletal disorders among banking employees. The study will provide feedback to the Banking Employees in consultation with expert of relevant field, as they can utilize the suggestions to reduce the extent of Musculoskeletal Discomfort. The findings of the present study will also beneficial to the occupational health specialist.

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Heuristics of Smartphones and Tablets to Identify Human Factors for Improving User Experience

Vidhita Dadarkar and Anupam Tiwari

Abstract Internet of Things, refers to products and gadgets around the globe that are now linked to the internet and automation, gathering and sharing data for improvement of lifestyle by innovation and automation. Early involvement of human factors professional(s) and iteration are the keys to successful smart device development. Human Computer interaction issues such as information presentation, usability, error tolerance. Smartphones and Tablets have become more commonplace, the user experience becomes increasingly important. NASA Task Load Index method to identify user performance metrics, Questionnaire for User Interface Satisfaction (QUIS), Subjective Workload Assessment Technique (SWAT) to identify and measure user time duration while using gadgets, cognitive effort load and stress and tension load to find better solutions. The research article will provide relevant human-centered strategies and Design Thinking solutions to designers, engineers and innovators to build and design smart Internet of Things products with better User Experience Interaction based on User Research, their physical needs and cognitive comfort.

Keywords NASA task load index · Subjective workload assessment technique · Smartphones · Tablets · Usability and user experience · Human factors

1 Introduction

The major aim of this case study is to identify cognitive and human factor problems of users while interacting with Internet and devices, Smartphones and Tablets for users to identify their comfort, cognitive problems and needs. The objective of this research paper is to find better solutions and strategies to improve and innovate smart products, Smartphones and Tablets that will help users to efficiently utilize the product or service and as innovators to create and build better products that enhance user comfort, cognitive demands and human factors through strategic design [1] Industry 4.0 is all about Automation, Internet of Things, Robotics, Analytics and Big Data

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developing a connection between technology and labor creating greater importance to highlight cognitive needs and requirements to boost performance, quality and operations to master the workflow. The study focuses on human beings interacting with Mobiles and Smartphones, analyzing areas of cognitive needs, response, work load, time, perception, and others to fulfill new cognitive demands associated with Smart products and innovation [2]. Smartphones deploying Android operating system and Apple's IOS System by 900% and 79% respectively and shows rapid development globally and shows higher requirement of Cognitive Ergonomics in the field [3].

2 Methodology

2.1 NASA Task Load Index

A survey was conducted on 450 users to identify their cognitive, physical, frustrations and requirements while using smartphones and tablets to identify pain points and for betterment of human factors and user experience interaction. An example of one of the respondents can be referred in Fig. 1. The following table presents the key users targeted for the overall survey.

2.2 Subjective Workload Analysis Technique

(Alternate method) conducted a survey on fifty to seventy-five years old user groups shown in Table 1. Figure 2, shows results of the alternated method conducted on the same users.

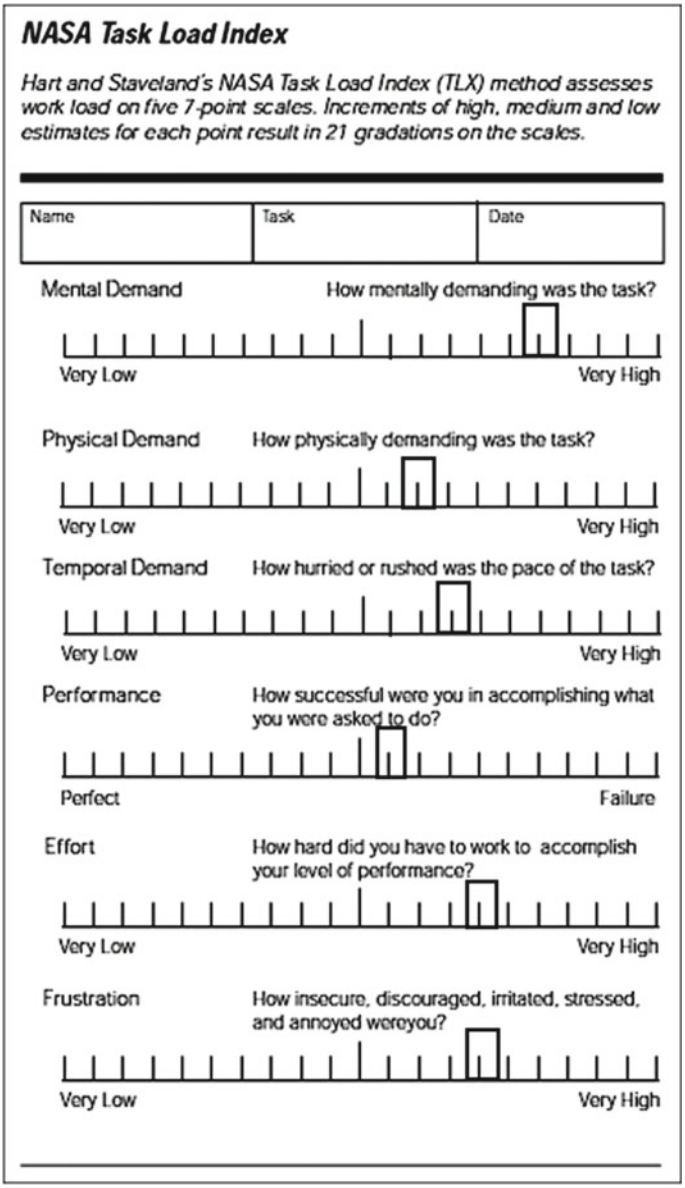


Fig. 1 The analysis on one of the users from the fifty–seventy-five years old user group of smartphones and tablets

Table 1 Details and age group of 450 users using smartphones and tablets targeted for overall survey conducted in this research paper

Number of users using smartphone and tablet	Age group
50	12–18
175	18–30
150	30–50
75	50–75

1. Time Load
   a. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
   b. Occasionally have spare time. Interruptions or overlap among activities occur frequently.
   (c.) Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

2. Mental Effort Load
   (a.) Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
   b. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
   c. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

3. Psychological Stress Load
   (a.) Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
   b. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
   c. High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

Fig. 2 The analysis on one of the users from the eighteen to thirty years old user group for usability of smartphones and tablets

3 Observation

According to Fig. 3, it was observed that 60% of thirty years old to 75% of seventy-five years old face a major mental load while using smartphones and tablets, while 70% of thirty-year-old to 90% of seventy-five years old feel frustrated while using smartphone and tablet.

4 Discussion

According to the Analysis, 95% of users ranging from eighteen years old to 30 years old don't have time and activities are very frequent hence time load is high. Mental load is comparatively low as they require less mental effort or concentration while using devices. Activity being automatic requires little or no attention [4]. Psychological Stress load is little and anxiety exists and can be accommodated. Product Design

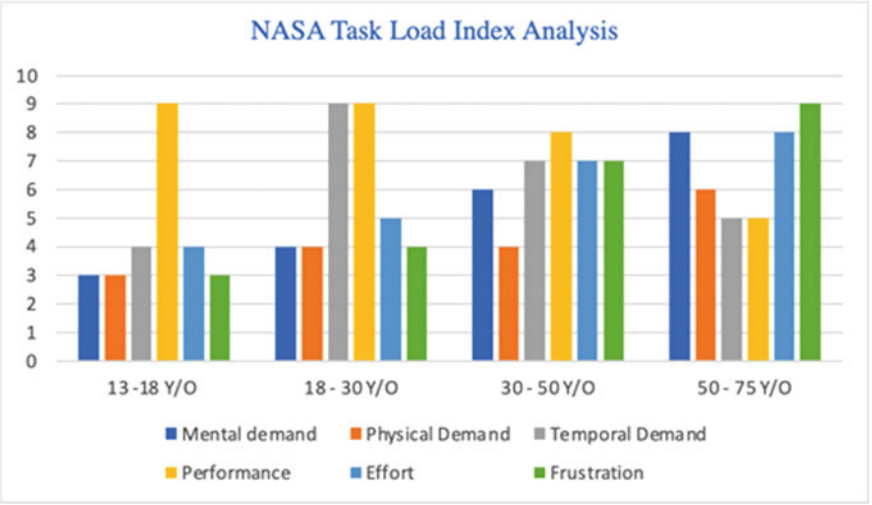


Fig. 3 An overall analysis of 450 years based on 2.1 Methodology

and development for wider user groups will add value to technological development [5].

5 Conclusion

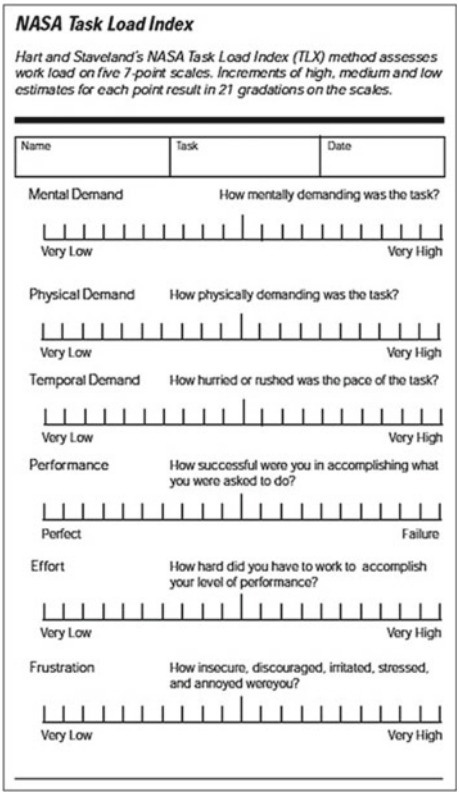
NASA TLX and SWAT Analysis was performed by circulating Google forms, Conducting Voice call and Video call interviews. The user groups were assigned a task to use their smartphone and download a product from amazon.com according to their choice and results were noted. Another task was to use their own favorite mobile application to complete the end goal of that specific application, use a smartphone of other brand than yours from your family and tell us your experience. In NASA TLX Method we found that 90% of users are in a rush and almost never have spare time while using a digital device, 87% of users have to make high efforts to accomplish the task. From the Subjective workload analysis technique, we found that 95% of users have interruptions and overlap activities daily. They have a very little mental effort while using digital devices as they require little or no attention while using smartphones. Psychological stress load is very little in term of usability but anxiety exists due to overlap activities and can be easily accommodated. Following are some measures and possible solutions that can be taken to reduce stress, frustrations, pain points to enhance the user experience and usability frustrations:

1. Developing minimalistic design, providing help and documentation to universal users and keeping the design user centric and universal are some key factors. Managing environmental settings to solve posture issues while using gadgets and products [6].
2. Eye Tracking tests in user experience design and development, to evaluate user experience and understand how user interacts with texts, large screen, small screens, size, colors to provide better experience and comport to eyes [7].
3. Following the design thinking process from empathizing the user, ideating the concepts, prototyping and getting tested your product or service with the user can give the best possible results. Strategic design goals can be followed to get the best results while developing a Smart product and interfaces for users to lower cognitive pain points and human factor problems while interacting with Smartphones and Tablets [8].
4. Five simple steps to lower cognitive pressure of users and innovating best products for users with high experience, usability and comfort.

    A. Empathising: Understanding the human needs involved.
    B. Defining: Re-framing the pain points multiple times in human-centric ways.
    C. Ideating: Brainstorming many ideas in ideation sessions
    D. Prototyping: Implementing prototyping and get it tested.
    E. Testing: Developing a testable mock-up before developing the final product to save time, costs and to get the best possible results for innovators, also for the users.

Appendix

A.



Source—https://en.wikipedia.org/wiki/NASA-TLX.

B.

1. Time Load
   a. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
   b. Occasionally have spare time. Interruptions or overlap among activities occur frequently.
   c. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

2. Mental Effort Load
   a. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
   b. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
   c. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

3. Psychological Stress Load
   a. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
   b. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
   c. High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

Source—https://ext.eurocontrol.int/ehp/?q=node/1588.

C. Questionnaire for user categories to understand pain points and frustrations while using a smartphone, tablet and touch screen devices.

1. Name.
2. Age.
3. Professional Background.
4. Do you have a Smartphone?
5. Have you ever used a Digital Tablet?
6. Top 5 mobile applications you use?
7. Your favorite mobile application?
8. How much physical load do you face while using a smartphone?
9. How much psychological stress do you face while using any digital device?
10. How much effort do you have to take while using a smartphone?
11. Do you face any pain points while using a smartphone, tablet?
12. How frustrated or stressed you are while using a smartphone?
13. Total duration using Gadgets, smartphone or tablet?

D. Activity for users to understand usability and actions while using a smartphone and mobile applications.

1. Order 1 product from Amazon.
2. Use your favorite mobile application and tell us the good points and pain points of your favorite mobile application.
3. Use a smartphone of another brand than yours from your family and tell us your experience.
4. How much time each user was taking to complete the task was recorded and noted.

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A Village in the City

Pulama Devi Oinam and Sonal Atreya

Abstract Understanding the significance of quality of life has become important these days which eventually has led us to the rediscovery of public spaces (both rural and urban) and their inter-relationship with the restoration of human dimensions in everyday life. We have realized the importance of social inclusions and connections in all these spaces with the intent of recognizing the importance of creating a sustainable environment model which will eventually contribute to the overall quality of life on this planet. With this intent and changes in the societies over time, it has become necessary to create more flexible spaces that support community participation to help in interacting better with the natural environment as well. This particular paper delves into understanding the vital relationship between urban open spaces at the neighbourhood level and their users which include components like physical and social factors which define them. Developing a framework to understand the concept of a self-sustained community and its need has long been recognized. However, we still fail to incorporate such concepts at the city level because of various constraints. We need to relook into successful village models in India and abroad and study the parameters in details of its self-sustainability concept. A comparative analysis can be further done to assess if a village model could be replicated at the urban neighbourhood level with the participation of the community by identifying gaps and using sustainable indicators to bring out a successful urban model.

Keywords Sustainable environment · Community participation · Neighbourhood · Self-sustained community · Human environment interface (HEI) · Human factors

Exploring possibilities of Urban regeneration of a neighbourhood involving the residents and bringing the community closer towards a sustainable approach by understanding Urban Ergonomics and Human Environment Interface (HEI)

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1 Introduction

The intent or concept of a village in the city is based on the idea of sustainable development and self-sustained communities and neighbourhoods. It is very important to identify and accept new ideas for continuous growth which also can help sustain the community for a longer period. It becomes essential for the people to interact and be able to contribute as a society to solve various problems and challenges by responding to the urban environmental set-up. In an urban environment at the neighbourhood level, it becomes all the more necessary that the community comes together, understands the environment and work towards it to improve the quality of life and sustain it for the coming generations [1]. As a sustainable model, society needs to be more flexible in terms of ideas and defining functions. It will need to adapt as time progresses to continue the community interaction and respond to the environment to create a sustainable built environment scenario at a micro-level in a city.

Now, when we discuss self-sustained communities or a sustainable environment, the best examples in India are a few villages that have responded to the environment as a community and taken it forward by creating a sustainable environment for the people. On the other hand, we also have examples of Indian villages where more than half of the population migrate to cities for better income and better facilities which in turn has led to cities to hold an added population that is more than its carrying capacity in terms of infrastructure and resources. There is a large floating population that migrates from villages in search of jobs and better income in cities. The best period for defining this has been this Pandemic which encroached on us at the start of 2020 and is still haunting us. The migrant daily wagers were the worst sufferers who lost their jobs because of the countrywide lockdown and going back to their villages had become a very difficult task and because of this, the whole system has become unstable and unsustainable.

Furthermore, in spite of all these challenges, we have also noticed many good examples of villages in India that have turned and looked back into the history and their traditional values and culture of successful community development and set up. We can say that slowly and gradually, we, as a country can look into these examples of implementing such models in all the Indian villages throughout the country and try to incorporate ideas in the city structure as well at the neighbourhood level which would be similar in terms of scale and proportion. We can look for solutions in these self-sustained villages to find out to which extent the human settlement and overall planning can be integrated given the current conditions and infrastructure of cities in India and can lead to forming sustainable neighbourhoods in cities.

We need to have a framework in which we can bring our traditional and modern practices together for a better outcome whether it is cities or villages which can lead to inclusive growth. This can lead to having efficient community participation and also involving local governance for the ideas to be implemented. In villages, farming of agricultural products, organic foods and medicinal herbs help communities in self-sustenance. Following the same path, we can introduce urban farming in cities

at the neighbourhood level which is the first basic step of creating a self-sustained community which is usually seen in villages. The need for such ideas has accelerated in cities during this pandemic even more where there was a lack of food supply due to countrywide lockdown. This approach can in the future help cities to self sustain at the time of crisis. The Village in the City approach develops a dynamic flow within cities. Thus, achieving sustainable development for human settlements in cities is the primary goal of this framework. This research looks into the possibility of creating a self-sustainable community model which will further help cities to regenerate the quality of life and their infrastructure.

2 History and Background

The introduction of a neighbourhood concept was for the first time materialized by Clarens Arthur Perry in 1929. According to him, such spaces should be more inclined towards a human centric approach by creating a pedestrian friendly environment leading to better social interaction of the residents [2] (Fig. 1).

Clarence A. Perry introduced six principles that support the design intent of a good neighbourhood. These principles revolved around physical, social and institutional set-ups or design concepts.

- The first principle was to avoid providing major arterial roads in the residential units rather streets should act as peripheral boundaries to avoid major traffic from getting into the residential zone.

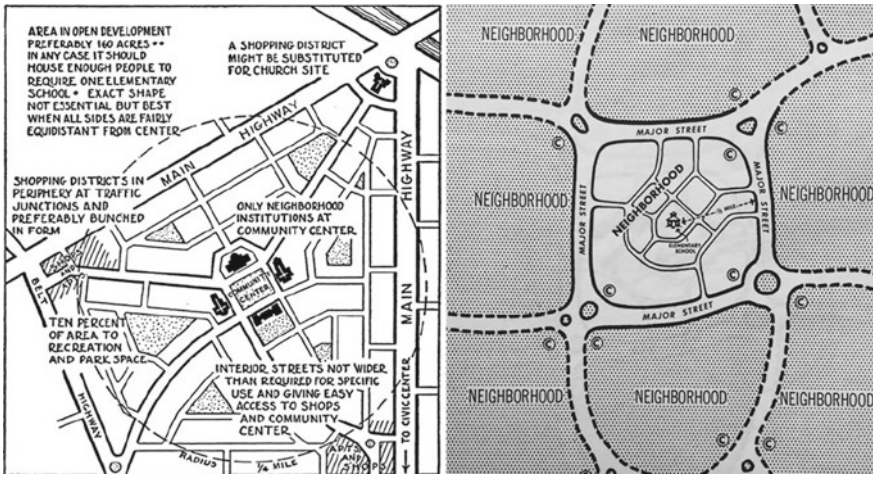

Fig. 1 A neighbourhood unit representation by Clarence A. Perry. *Source* https://www.cnu.org/publicsquare/2019/01/29/once-and-future-neighborhood

- The layout of streets should be curved and cul-de-sacs need to be introduced to create a peaceful movement of traffic and a quiet residential ambience.
- There should be at least one elementary school provided in the neighbourhood unit to cater to the current housing units in that area.
- There should be a provision of recreational spaces and parks to cater to the needs of the residents of the neighbourhood.
- Institutions and schools should be grouped with a common point or a centre point with the residential units nearby.
- The number of shopping zones or areas should be adequate to cater to the neighbourhood population which also can be planned and cater to other adjacent neighbourhoods.

Now, talking of cities, the early ones developed in many places all around the world. Ancient cities were found in Indus Valley, China, Mesopotamia etc. One of the largest ancient cities in the world was Mohenjo-Daro. Its planning is still referred to as a great and one of the most successful models in terms of both physical and social infrastructure [3]. In a way, we can say that in modern cities of India, we can have many Mohenjo-Daro(s). We can take ideas and imply them at the hierarchy of neighbourhood level for inclusive growth in today's cities. All the ancient cities were unique in their ways of settlement planning and functioning. It mostly was based on the geographical context and culture of the dwellers (Figs. 2 and 3).

Now coming to the definition of neighbourhood, it can be termed as sub-divisions of urban areas and rural areas. So when people start living in these subdivisions, they start to form communities. All these communities differ according to their locality and the social context of a specific location. So, in a way, it can be defined as an

Fig. 2 Mohenjo-daro settlement pattern. *Source* https://www.nationalgeographic.com/history/article/mohenjo-daro

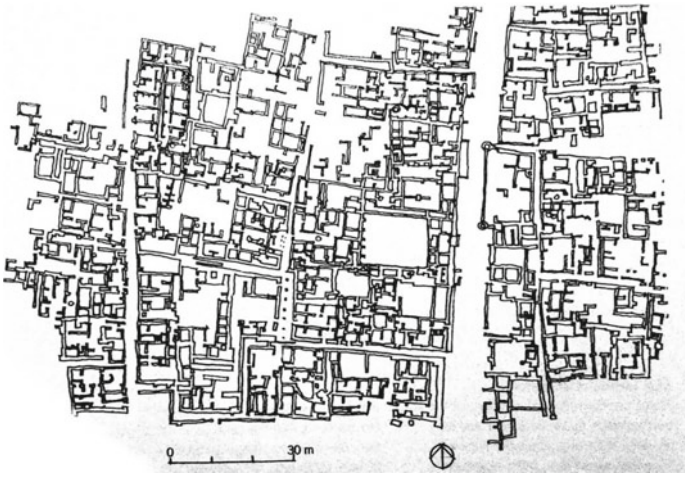

Fig. 3 Mohenjo-Daro layout plan. *Source* https://blogs.brown.edu/arch-0760-s01-2019-spring/2019/03/31/ground-plans-akrotiri-vs-mohenjo-daro/

environment created by the dwellers having the same social structure and cultural values which strengthens with time [4].

In relation to this, the main objective of the experiment is to develop a human settlement model which revolves around sustainable ideas. The concept of a self-sustained community or a neighbourhood has long been recognized. However, we still fail to incorporate such concepts at the city level because of various constraints. There is a need for a better understanding of successful models and a look into the solution of how a village model needs to be understood and applied at the city level to create a self-sustained community, connecting more with nature and by respecting it.

Taking it further ahead, the following objectives were taken into consideration:

- To identify and explore similarities between a successful village scheme and city neighbourhood development patterns.
- to explore the typical constraints found in a city for the formation of a self-sustained neighbourhood
- To come up with a solution of creating a self-sustained neighbourhood by strategizing a framework.

3 Problem Statement

The importance of developing a framework to understand the concept of a self-sustained community has long been recognized. However, we still fail to incorporate such concepts at the city level because of various constraints. There is a need for a better understanding of Urban Ergonomics, understand the human factors and

the relationship with the environment. We also need to look at how a village model works and how it can be applied at the city level to create a self sustained community, connecting more with nature and by respecting it.

4 Aim

To outline a conceptual framework and come up with a solution of creating a self-sustained neighbourhood at the city level by identifying the indicators of Human Environment Interface (HEI) and understanding and solving the complexities of human factors and the environment in an urban setup.

5 Methodology

As a part of this study, we shall get into understanding various case studies of community living sustainably depending on the local context. We need to understand the ergonomics of an urban as well as a rural setup. In order to understand, various indicators of Human Environment Interface (HEI) like well being, safety and usability factors need to be identified based on which the purpose of this study shall be taken forward [5]. In the second stage of this study, a comparative analysis is to be done between a community living in a village and a community living in a city. We will identify the common points and identify the solution of how a successful village model can be replicated in the context of a city**.** The sustainable community concept and design principles can prove to be a successful example to the overall spatial development aspects of human societies which can be complemented by the fact that any social organization or a set-up has its physical, regional or local components which makes it unique in its own way.

A self sustained neighbourhood can have the following factors of defining it (Fig. 4).

6 Case Study

6.1 Mawlynnong Village, Meghalaya, India

Mawlynnong is a village in Meghalaya that follows the concept of Sustainable Livelihoods and promotes community interaction and integration. The area of the village is around two square km [6].

Following are the ways that the villages have maintained a sustainable approach:

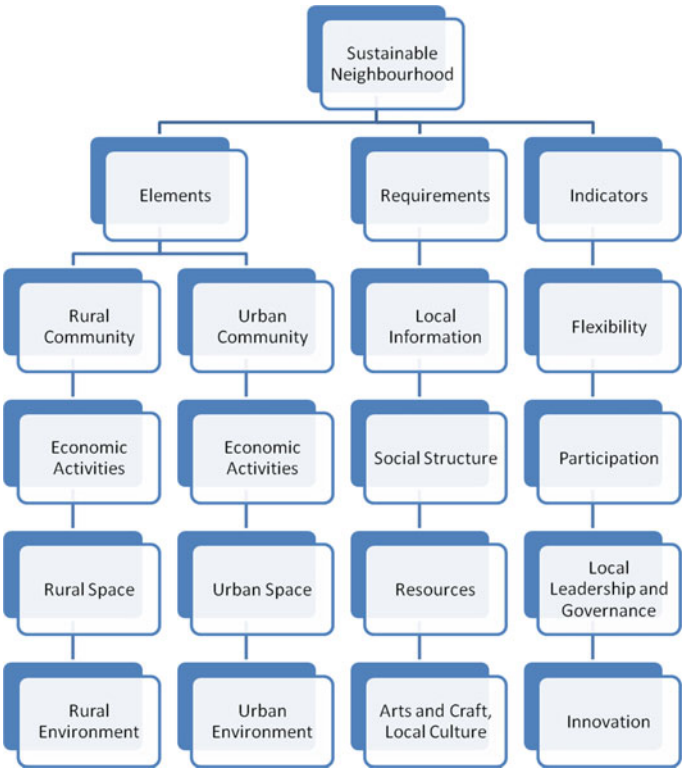

Fig. 4 Factors defining sustainable neighbourhood

- As a source of income and with the mindset of generating money for the upliftment of their village, tourists pay Rs. 50 as an entry fee which is then invested in maintaining the cleanliness of the village.
- The houses which are built follow the local architecture style which is easy to maintain and construct.
- Majority of the population work in the fields for food production.
- The villagers maintain and come together as a community to maintain the society, in terms of waste segregation, they are well aware of how to distinguish between types of waste and bamboo dustbins are placed at regular intervals in the whole locality.
- All children of the village must enroll in school for education. The children are taught how to maintain hygiene and keep the community clean at a very early age, they have been also taught to collect water through the rainwater harvesting process by placing a stone basin at the front of the house in which rainwater gets collected.
- The village council also makes sure that the children are made aware of global warming and they are also taught how to value the natural forests.

Fig. 5 Mawlynnong Village. *Source* http://tourismwings.com/2019/03/14/an-escape-to-the-asias-cleanest-village-meghalayas-mawlynnong/

- Every household has a toilet which helps to maintain hygiene and there are other public toilets also which have been constructed for the tourists who visit the village (Fig. 5).

6.2 Auroville

The lands of Auroville covers around 20 km^2 of land, plantation and community living. From the start of Auroville, the residents living there have always followed a sustainable approach for a better quality of living [7].

Following are the factors Auroville has considered in its sustainable practices:

- Garbage segregation is always done in the communities of Auroville by separating the biodegradable waste and using it in the fields.
- There are water catchment areas in the city to recharge groundwater in the area.
- Reuse of biomass and plant nutrients
- Saving Water Resources
- Improved Handling of waste matter by collecting solid waste in the chambers constructed below toilets. So, after a year, when the faeces have dried, they are used as rich fertilizers.
- Cutting down soil and water pollution as there is no sewage wasted (Fig. 6).

Fig. 6 City of Auroville. *Source* https://auroville.org/

6.3 Piplantri, Rajasthan

Piplantri is a Gram Panchayat in Rajasthan consisting of 12 hamlets. The terrain is hilly and is known for marble quarry which is located partly in the area. Due to the loss of green cover and its hilly terrain, water tables had come down and the well ran dry over a period of time [8].

But, nowadays, this village had adequate water supply, wide roads which are paved and power supply with optimum street lighting. There are upgraded health facilities and improved social infrastructure with better awareness of education and better quality of life. More than 1.5 lakh trees have been planted in the last decade for a greener environment.

The key factors in its development is mainly due to people's participation in the decision making and supporting local self governance. These have been the key factors in its upgradation of life in which the intent has been human centric by identifying and catering to providing quality human environment and its usability.

7 Site Location and Analysis

7.1 Site Location-Chittaranjan Park

There are 15 planning zones in the NCT of Delhi and 8 of them fall in the urban category. The site location falls in one of these 8 urban zones in zone F. Now Zone F is further divided into various subzones and the site area (ward 190) falls under subzone F-9 [9] (Fig. 7).

Fig. 7 The neighbourhood of Chittaranjan Park. *Source* http://e.duac.org/images/pdf/3%20Chittranjan%20Park-1.pdf

7.2 Land Use

The land use cover of Ward 190 is mostly residential with 30% green cover. Every pocket has a park or a green area defined for recreational activities and activities of children (Fig. 8; Table 1).

8 Result

Through observation and secondary data available, it has been found that in ward 190, pedestrian walkways are inadequate, there are encroachments on pathways by vendors, zonal parks are not well maintained and designed, there is lack of proper parking space in and around the market area, drains are not cleaned regularly as a result of which there are water logging issues during monsoon which ultimately can lead to health issues of the residents in the neighbourhood [9]. As a proposal, dedicated and adequate pedestrian pathways, cycle tracks with proper signage, design proper ramps and a tactile path for blind to solve the walkability issue, there has to be a dedicated space defined for street vendors to solve the encroachment issue. We also need to propose the idea of separating different types of wastes at the point of collection and provide dedicated waste chambers. In the process of executing these

Fig. 8 Land use plan. *Source* http://e.duac.org/images/pdf/3%20Chittranjan%20Park-1.pdf

Table 1 SWOT analysis

Strength	Weakness
• Concept, design • Water management, waste management, passive—solar energy, agriculture • Flexibility, adaptability • Local government • Community life (housing and working community)	• Organisational structure, ownership pattern (foundation) • Social, sociological basics, lack of community participation (occasional) • Lack of awareness, of sustainable community involvement
Opportunities	**Threats**
• Acquisition of landed property • Infrastructure developed • Accumulated experiences • Integration into the settlement work	• Lacking social needs, interest • Changes in external conditions • Social disintegration, poor maintenance (community building)

proposals, the local residents need to come forward as a community and respond to the environment with the help of the urban local body and solve the complexity of human factors by coming together and working towards it.

9 Discussion and Conclusion

A city neighbourhood is like veins of an urban set-up that supports a city structure culturally, socially, economically and physically. From the site chosen for the implementation of a self-sustainable community, we can conclude that when there is a framework that supports sustainable values, it becomes easier to implement them with increased participation of the local community of that area. There can be workshops by experts on how to create an awareness of sustainable values, preserve socio-cultural values and inculcate them in children at a very early age so that the coming generations take these ideas forward and we can create a sustainable built environment structure to provide a better quality of life. This can be done by identifying the indicators of Human Environment Interface and understand Urban Ergonomics in terms of well-being, safety and usability [5]. By increased participation of communities, we can experience better physical infrastructure with the support of local governance and get all these ideas implemented. A sustainable approach to such set-ups can be applied in the case of other neighbourhood models for holistic development. Government and policymakers need to engage themselves and strategize to attract the local residents and the community by rethinking the planning, development and management for a better future.

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Comparative Visual Analysis of Brick Architecture Ornamentations of the Ahom Monuments in Sivasagar, Assam, India

Saurav Khuttiya Deori and Utpal Barua

Abstract Assam has a rich history of the Ahom dynasty for 600 years. With the first Ahom King Sukapha (A.D. 1228–1268) leadership, they set up their first capital in the Charaideu district of Assam. As for which, most of the Ahom architectures are observed in and nearby Sivasagar and Charaideu area of Assam. Most of the Ahom monuments are preserved under the Archaeological Survey of India (ASI), Assam and Directorate of Archaeology, Guwahati, Assam. These monuments were constructed using mostly bricks, stones and mortar. Noticeably, the ornamentations in the brick monuments have managed to survive in fragments and sections; this is due to the effect of natural causes and the climatic condition of the environment. In some cases, the restoration process reduces the ancient aesthetic due to lack of understanding of the underlying design principles of ornamentation. Most historians and scholars have studied the iconography and archaeological findings of these monuments; the study on Ahom architectural ornamentation is significantly less. A pilot study was conducted to identify the surviving ornamentation in brick architecture monuments. Based on the identification, a categorization theory has been adopted to segregate the data. The categorization is based on the architectural sections of monuments that primarily includes motifs and pattern types. This paper identifies and compares the visual elements of ornamentation using formal analysis. It discusses the underlying design principles of ornamentation. The results and analysis of this paper provide a significant contribution to the conservation of traditional art and early architectural ornamentations.

Keywords Ahom architecture · Ahom motifs · Archaeology · Conservation

1 Introduction

The Ahoms ruled Assam for nearly six hundred years, from the early twelfth century till eighteenth century. Their reign had a significant impact on the culture and heritage

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of Assam. Historically, the Ahoms are from the Tai community[1]; they entered Assam from Mong Mao, crossed the Patkai hills, and settled in the Brahmaputra valley [1]. In the early seventeenth century, the art and architecture of the Ahom flourished during the rule of King Rudra Singha (A.D. 1696–1714) [2]. Today, the heritage of the Ahom architecture can be observed in many stone and masonry monuments. Many stone and brick monuments can be observed in the Sivasagar and Charaideu area of Assam. Most of the Ahom masonry architecture can be dated back to the seventeenth century from the rule of king Rudra Singha (A.D. 1696–1714). The initial constructions were mostly timber and bamboo; gradually, they shifted their construction raw materials to stones and bricks [3]. Most of the stone and brick ornamentations are well preserved by the Archaeological Survey of India (ASI) and the Directorate of Archaeology, Government of Assam. However, with due course of time, the brick monuments are able to survive in fragments. This is due to the clay material type with environmental conditions and natural causes. During the pilot study it was observed that in some monuments, refurbishment of some ornaments lacks in traditional aesthetics, resulting in disharmony, and disunity in the overall ornamentation. To preserve these ancient art, this paper aims to study the ornamentation of the Ahom brick architecture monuments.

According to Oxford dictionary, 2020 "an ornament is a thing used or serving to make something look more attractive but usually having no practical purpose". Its origin is from Old French *ournement*, and from Latin *ornamentum* 'equipment, ornament', from ornare 'adorn'. The verb dates from the early eighteenth century. Ornamentation are decorative elements added to something to enhance its appearance. Verma [4] in his book 'Ornamentation of in Indian Architecture' states that, "For a building to become architecture, it must be thematically essentialized through a process of ornamentation. The product of this proceeds is 'ornament'—something employed to adorn, beautifully, or embellish, or that naturally does this" [4]. Most ornamentation exhibits motifs and patterns. The motif in architecture is structural or decorative designs, especially found repeated in buildings and the patterns are design or decorations in repetition on shapes, forms, lines and colors. This paper studies the ornamentations focusing on motifs and patterns. It analyses the visual forms and shapes of the motifs and patterns along with variations and compositions.

The study on motifs and patterns of the three iconic monuments of the Ahom architecture—Rang Ghar, Talatal Ghar and Kareng Ghar are taken into consideration. These monuments are famous tourist spots of Assam, geographically the Rang Ghar and Talatal Ghar are situated in Sibsagar district. The Kareng Ghar is approx. 16.4 km away in Charaideu district (Fig. 1).

[1] Tai is a large ethnic group consisting of various subgroups currently scattered mainly across parts of Southeast Asia and South Asia (especially Northeast India), having followed different migration patterns from their original homeland, believed to be in Yunnan province [10].

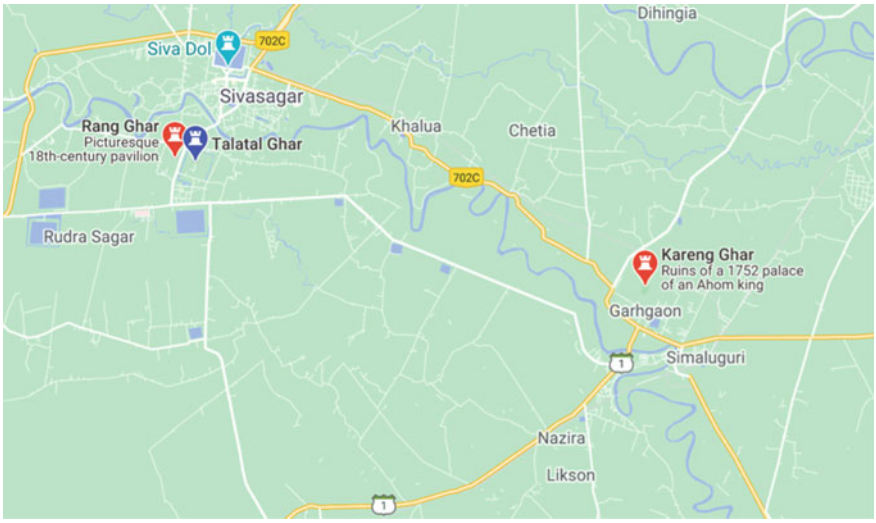


Fig. 1 Google map screenshot of the geographical locations of Rang Ghar, Talatal Ghar and Kareng Ghar

2 Method

As mentioned earlier, the Ahoms have been associated with art and architecture in Assam; the historical approach was considered to study the early scenario of their reign. The selected monuments are massive in size and have a unique architecture type of their own. Multiple site visits are conducted for video and photo data focusing on the architectural ornamentations. As the data was in large number, categorization theory [5] is considered. His study 'Categorization Natural Language and Design' states that organized categorization can lead to concepts, and with that visual information can be controlled [5]. In principles of categorization [6] states that "instead of categorizing objects into large numbers of finely discriminate and tightly organized concepts, the mind automatically selects the cognitively economical option of neglecting the infinite differences among objects to behaviorally and cognitively usable proportions. The categorization process treats nonidentical objects as equivalent, when differences are irrelevant to the human response" [6]. With relevance to the data sorting, [7] has considered this theory to sort the data based on motifs and patterns on a terracotta ornamented monument [7]. There are three levels in considerations of categorization—*Superordinate level, Basic Level and Subordinate level.* The motifs and patterns are mostly observed in the walls, pillars, roof and the entrance sections of the selected monument; hence, in Superordinate level, the exterior and interior sections of the monuments have been considered. This includes photo data from the entrance, wall, pillars and roof of the monuments. The Basic level has two sections, it includes segregating the data to Motifs and Patterns from the superordinate level. In the third level i.e., the Subordinate level, the motifs and patterns are sorted into

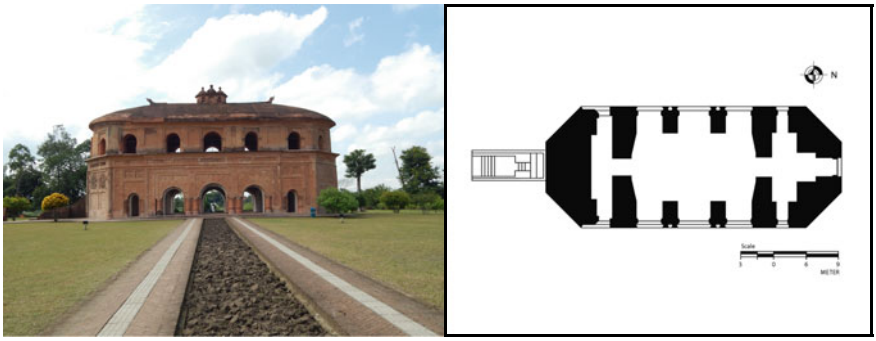
various types. These motifs types are *floral, compound, animal and symbolic type*; the patterns types are *organic and floral types.* The floral motif include single or multiple flowers, the Compound type includes motifs composed with flower, animal, creatures, human, birds and man-made forms. The symbolic motif includes mythical creatures, religious symbols. The animal motif include humans, wild and domestic animals and birds. With the complexity of these large data, five designers were asked to categorize the photo data using the mentioned categorization process. The categorization done by each designer is then compared to refine the taxonomical structure based on commonalities.

After the categorization, coding of data is done to reduce data redundancy. It considers all the levels of categorization, i.e., the name of the monuments, the sections, motifs or patterns and their types, and numbering. For example, a floral motif from a wall of Rang Ghar is coded as: *Ran-M-Wa-F-01*. *Ran* for Rang Ghar, *M* for Motif, *Wa* for the section i.e. Wall, *F* for floral motif and *01* is the serial number of the motif type. With the coding of the data, linear extraction of the motifs and patterns is done using vector software Adobe illustrator 2021 to study the shape and form in the composition. Considering the linear extraction, variation analysis of the extracted motifs and pattern is done. The quantitative data showcases the dominating motif and pattern types. Further, the study considers visual analysis based on shape, form, colour and texture. The study helps to understand the nuances in the visual compositions of the motifs and patterns.

Data gathering. Photos and video data are collected from Rang Ghar, Talatal Ghar and Kareng Ghar. Semi-structured interviews are conducted with Senior Conservation Assistant, Sivasagar Circle (ASI), Archaeologist and a private museum owner from Sivasagar area. For secondary data, early photographs of the three monuments are collected from ASI to study and compare the refurbished sections of the monuments. Library and the internet were other sources of secondary data.

3 Results and Discussions

Rang Ghar. Pramatta Singha (A.D. 1744–1751). The masonry architecture of Rang Ghar is unique of its own (Fig. 2a). The monument has a parabolic shell-roof style. The key play of the Rang Ghar (Fig. 2b) displays a rectangular-shaped plan with trapezoidal ends. The construction has two storeys with multiple openings. The openings are decorated with multifoil arches with pillars. These types of entrances and opening with arches often relates the Indo-Islamic architecture style of India. The monument is constructed as a royal grandeur for witnessing outdoor games, such as buffalo-fight, falconry, outdoor games, etc. [8]. The architectural ornamentations are rich with various floral motifs, symbolic motifs and compound motifs with creepers, vines, animals, mythical creatures. The organic patterns with florals and vines are also observed in many sections of the monument. Some remains of terracotta bricks in the pillars of the entrance of the upper storey have a resemblance with the entrance pillars of Ghanasyam House [7] of the Joysagar area, Assam.



(a) (b)

Fig. 2 **a** Font side of Rang Ghar with key plan, **b** source ASI

The ornamentation of the monuments displays exceptional skills of pargeting of the artisans. Multiple panels with rectangle shapes and multi-arch frames are seen in motifs and pattern compositions. The overall arrangements of motif and patterns design displays equal visual distribution resulting in balance and harmony in the architectural ornamentations.

Talatal Ghar. It is situated near Rang Ghar, Joysagar (Lat. 26°–58′ N; Long. 94°–41′ E). According to historians, Rangpur[2] was one of the capitals of Ahoms, and Talatal Ghar was one of the largest and extended masonry buildings of that capital. Initially, the construction materials were of wood and bamboo, later in 1765 A.D., with the initiative of king Rajeshwar Singha, the monument was rebuilt using bricks and mortar [8]. The building showcases various chambers and multiple floors and openings Fig. 3b. The openings are created in all the sections of the architecture. According to Barpujari [3], the monument was originally a three-storey building with a subterranean storey. The upper storey has almost disappeared; only a few sections and fragments are present as remains. The present ground floor is almost filled up with soil. The monument was rich with various motifs and patterns. Though with time, most pargeting ornaments are in bits and pieces; the surviving motifs and patterns are studied and analysed. There are similarities in motif's composition with Rang Ghar; most of the compound motifs are composed using rectangular and multifoil arched frames with branching of stems, flowers, humans and animals. The patterns are primarily observed in the upper sections of interior entrance walls, sidewalls, below the parapet of the building and some pillars. The patterns are composed using repetitions of branch out vines, flowers, animals and man-made forms. It also displays intertwined vines and leaves with flowers in a structured manner.

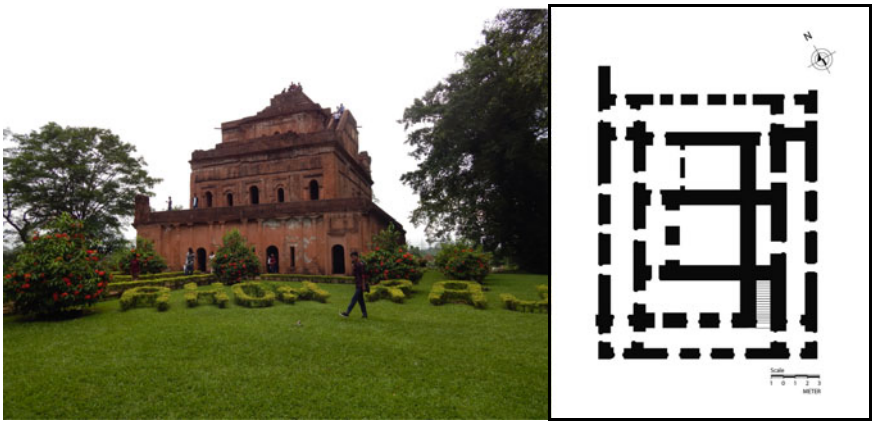
Kareng Ghar. The Kareng Ghar is situated in Garhgaon under the Charaideu district of Assam (Lat. 26°–58′ N; Long. 94°–41′ E). It was the first capital of the Ahoms. The monument was built during the reign of King Rajeshwar Singha (A.D. 1751–1768)

[2] A city founded by Ahom King Rudra Singha during 1698 A.D.

(a) (b)

Fig. 3 **a** Talatal Ghar Side entrance view with its key plan, **b** source ASI

[8]. According to ASI, this place is also named Ahom Raja Palace Fig. 4a. This is because the monument is considered to be a royal palace. The masonry architecture has four storeys, with an open terrace for each floor. The elevation of each floor leads to a pyramidal effect as a whole. The monument has many pillars designed with stylobate and columns with multiple openings. Most of the upper sections of the monument got damaged due to natural causes. Kareng Ghar has lost most of its ornamentations in terms of motifs and patterns out of the two monuments. Most of the monument sections are being refurbished; hence, difficult to differentiate the original pargeting from the refurbished one. Few of the motifs and patterns have survived in the walls and pillars of the monument.



(a) (b)

Fig. 4 **a** Kareng Ghar Side entrance view with its key plan, **b** source ASI

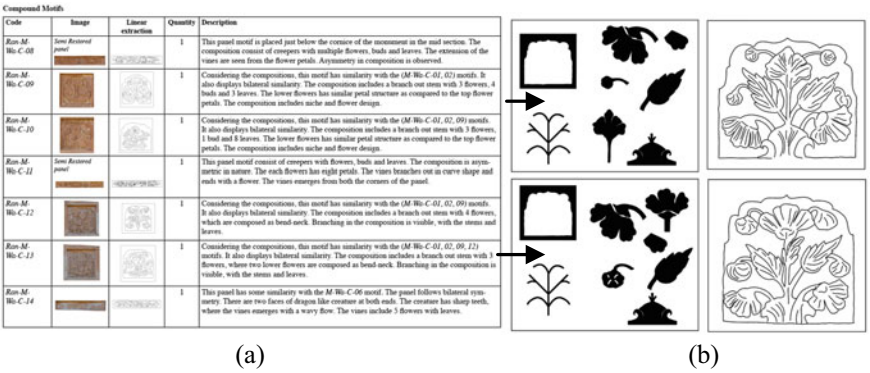


Fig. 5 **a** Table of variation analysis and linear extraction of compound motifs of Rang Ghar; **b** elemental composition study of *Ran-M-Wa-C-09 and Ran-M-Wa-C-10* compound motifs shapes, form and branching type

3.1 Analysis of Motifs and Patterns

With the photographic data collected, each motif and pattern of the monument are traced in a linear form using Adobe Illustrator software, along with variation analysis considering the shape and forms as shown in Fig. 5a of Rang Ghar. Considering compositions of each motif and pattern and its aesthetics, dissecting to singular forms are done, as shown in Fig. 5b. This helps to understand the visual considerations of the early artisans while developing the ornamentations. This may include the type of flowers, leaves, vines, use of living organisms, or mythical creature, man-made forms and many more. A similar process has been followed on Talatal Ghar and Kareng Ghar.

Quantitative Results of Variation Analysis

With the help of variation analysis, quantitative data motifs and pattern types is obtained. In Rang Ghar, out of 279 motifs, 83.9% are floral, 14.7% are compound and 1.4% are symbolic with no animal motif. In terms of pattern variations, Rang Ghar has six variation types in organic patterns, with no geometric patterns. The Talatal Ghar has comparatively fewer survived motifs and patterns than Rang Ghar. The collected data displays only eight survived motifs, out of which 50% are floral motifs, 12.5% are compound and 37.5% are animal motifs with no symbolic motifs. There are 19 pattern variations, out of which 89.5% are organic patterns and 10.5% are geometric patterns. With the collected data from Kareng Ghar, it was evident that most of the ornamentation is in a fragmented state. Only four motifs are observed in the Kareng Ghar, resulting in 60% floral, 20% Compound and 20% animal motif. The patterns are comparatively more. A total of 12 patterns variations are observed, with 75% organic type and 25% geometric type.

Overall evaluation displays the domination of floral motifs and organic patterns amongst all the selected Ahom monuments. The result strongly indicates their interest

in nature-based forms and elements. It was also observed that the lotus flower had been repeatedly used as a part of the ornamentation in floral motifs.

Shapes and Forms

For visual analysis of the ornamentation, the shapes, form, color and texture of the extracted motifs and patterns are considered. Each motifs and patterns has undergone linear extraction after the variation analysis. Primarily the shapes and forms in the composition of motifs and patterns are studied using formal analysis. The composition are dissected to identify its elements.

Floral motifs. In Rang Ghar, the floral motifs are in large number. They have multiple petals with variations in petal counts, shape and petal layers. The singular floral motifs are more in numbers compared to other motif types. These motifs are composed in a pattern type all over the entrance arches, wall, near pillars and columns. Most of the existing single floral petals are rounded in shape rather than pointed. The motifs have two-layer petals with a circular core. Repetition of petal shapes is considered to create unit forms; some unit forms display affinity[3] and radial symmetry. Union of two or more layers of petals are observed in the floral compositions.

Comparatively, Talatal Ghar has significantly fewer survived singular floral motifs. The existing lotus motif has strong similarities with some of the front wall singular lotus motifs of Ghanasyam House [4], as it has a circular base. The rounded petal types have similarities with most of the ornamented flowers of all the selected monuments.

Kareng Ghar, on the contrary, had lost most of the ornamentations due to natural causes. The collected data displays a four-petal singular floral motif. The motif has a flower inside a square border, with each petal pointed towards every corner of the square border. The petals have a pointed edge.

Compound motifs. The compositions of compound motifs in Rang Ghar are a mixture of flowers, vines, leaves, animals and mythical creatures. Most of the compound motifs display bilateral symmetry in branching. Affinity in compositions are observed in the motifs with floral types and branching of buds and vines. This leads to unity in compositions. Mand-made forms like framed multi-foil arches are observed in most. Representational forms of wild animals, plants, flowers, birds and creatures are included in compound motifs. Repetition of shapes like vines curves, flower shapes, man-made shapes in terms of direction position and space are considered while composing the motifs. Repetition of shape, size, direction, and position of the elements are observed and most of the composition displays bilateral symmetry.

In Talatal Ghar, compound motifs have multiple flowers with petals in both rounded and pointed shapes. Man-made forms like a rounded pot with emerging floral stems. Most of the motif seemed to be placed inside a multi-foil arch frame.

[3] Elements within a particular natural form- cells, section or layers that make up a surface. These elements are not strict repetitions, but vary individually or progressively to conform an overall shape or structure [9].

These types of composition similar to some of the *niche-and-flower*[4] designs of the Indian carpets of the Mughal era. Some compound motifs seemed to have fragmented human figures with hunting, standing and resting postures. The human figure shape has similarity with the costumes of Mughals during the seventeenth century—'Jama coat' and 'Juti'. Although most of the composition is deteriorated due to natural causes, the shapes and form in the composition lead to humans with dynamic and static postures, plants with branching with pointed leaves and animals like horses and deer. Some panel motifs are placed on the left exterior walls of Talatal Ghar near the roofed stairs. It has multiple flowers extended with vines and leaves. The petals are both rounded and pointed in shapes. Most of the existing motifs display asymmetry.

Kareng Ghar's compound motifs are in fragments and are in a faded state. Hence it was difficult to extract precise forms. The existing forms and shapes display flowers with curved leaves with pointed edges repeated with varied shaped flowers.

Animal and Symbolic motif. In Rang Ghar, the symbolic creature is placed in the interior entrance arches of the ground floor facing each other. There is a total of 4 of these symbolic motifs. The motifs have a closer resemblance to the face of *Makara*[5] and the body of *Yali*.[6]

A motif of the human form, standing with a raised hand, is seen in Talatal Ghar. The form looks like the human figure is wearing an outfit resembling the Mughal outfits, like Jama coat, Paijama, Juti and turban. The human figure is composed inside a multi-foil arched frame. It is placed on the left exterior walls of Talatal Ghar near the roofed stairs. The collected data of Kareng Ghar do not show any survived animal and symbolic motifs.

Patterns. Rang Ghar, most of the organic pattern follows bilateral symmetry. The composition includes repetitive use of two curve-shaped vegetal leaves surrounding a flower. This pattern is repeated all over the walls of the monument. The composition includes extended vines from a multi petal flower vertically. It exhibits a seamless design with leaves and vines with two-directional reflectional symmetry. The floral petals are rounded in shape, and the leaves have a pointed edge. Repetition in shape, size, colour and directions is observed. Directional variations like alternate direction are observed in some patterns [9].

In Talatal Ghar, some panel patterns consist of a bipinnately compound leaf stacked one pair after another. The leaves are pointed in shape. The compositions display bilateral symmetry, one-directional reflection symmetry, and asymmetry. In some panel, it consists of the repetition of alternate flowers stacked one after another, the sepals of the flowers connect the sepals of the flower above it. The floral petals consist of both rounded and pointed shapes. The interior section of the monument has many fragments of organic patterns over the entrance arches and some of the walls. The compositions of the patterns display details of flowers intertwined leaves with branching out of vines in structured, repetitive patterns.

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[4] https://www.metmuseum.org/art/collection/search/452554 [11].

[5] *Makara* is a legendary sea-creature in Hindu mythology.

[6] *Yali* is a mythical creature seen in many South Indian temples, often sculpted onto the pillars.

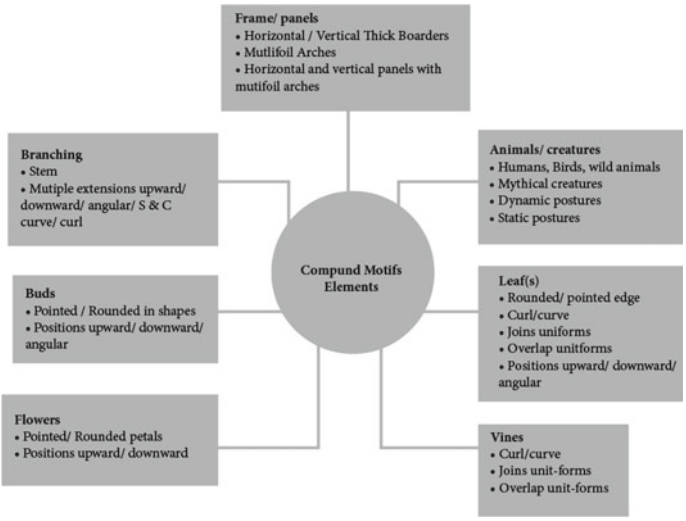

Fig. 6 Considerations of variety of unit-forms used in compound motifs with variation and position types

In Kareng Ghar, the existing patterns are a mix of organic and geometric patterns. In some of the pillars, vertical line strips, crisscross patterns are observed. As compared to geometric patterns, the organic patterns are more dominant. The use of flowers with pointed and round petals is standard, with pointed edge leaves. Man-made forms with wave patterns are seen in the compositions.

The analysis of each motif and pattern reveals unit forms like stem, flower shape, vines curves with S and C shapes, leaves, buds, man-made forms, animals, and branching are repeatedly used as the core elements of compositions (Fig. 6). It is observed that most singular motifs are placed without borders. The singular motifs display **radiation** as a form; this is due to the concentric structure of the flowers. **Gradation** in singular motif placement are observed in Rang Ghar walls, with spatial progression, where there is a gradual change of the unit forms in terms of size positions. The compound motifs are always composed within borders like arched framed rectangles, vertical panels with and without arches, horizontal panels with arches. The analysis also reveals that **bilateral symmetry** is most common in compound motifs. The compound motifs and patterns display **similarity and repetitions** in (flower, leaves, stems, buds, vines, buds, animal) shapes and types. **Contrast** in unit-form's shape, size, position and direction taken into considerations by the artisan for development of motifs and patterns. In most of the bilateral motifs, **concentrations** towards and away from lines and points are observed. The use of symbolic and animal motifs is very less compared to floral and compound motifs. According to Wong [9], **the anomaly** is the presence of irregularity in a design in which regularity still prevails, with the motive to attract attention, relieve the monotony, transform regularity, and break down regularly. These features are

seen in most of the floral patterns placed over the entrance walls of Talatal Ghar. The patterns also exhibit bilateral symmetry with the two-way continuance and four-way continuance in compositions.

Color and Texture

All the masonry buildings of the Ahoms radiates a tint of red colour due to mixtures of bricks and mortars. According to ASI, the early mortar composition includes mixing lime (limestone and snail shell), pulses, resin, hemp (*canarium resiniferum*), molasses, fish, etc. Again, the fusion of molasses and limestone leads to the creation of red tint. Texture development in the walls and pillars of the monuments are observed. Tactile texture has a distinct kind known as organized texture, where the mortars are striped into smalls bits in the shape of overlapped leaves on the ceiling walls, lines and parallelogram-shaped strips in pillars. The use of organized texture leads to a new ornamented surface as a whole.

4 Conclusions

The collected data made it evident that ornamentation in architecture was a significant consideration in Ahom masonry architecture. The details of motifs and patterns showcase the exceptional craftsmanship of the artisan of that era. The variation analysis of the motifs and patterns discloses the domination of floral motifs and organic patterns. The lotus flower is commonly used in Ahom architectural ornamentation. The visual analysis indicates that the use of multifoil arches in motif compositions resonates with Indo-Islamic architecture. Although considering the influences, the motifs and patterns strongly showcase their uniqueness in compositions and visual distributions of the unit-forms. The variations in flowers, leaves and use of multiple unit-forms retaining harmony and balance flourish the design understanding and considerations in compositions.

The study sheds light on the consideration of bilateral symmetry in most of the compositions and visual distribution with spatial arrangements. Repetition in shape, size and form are also observed. Design principles like repetition, gradation, anomaly, contrast, similarity, radiation and concentration are in the compositions. The comprehensive study provides a handful of information on the underlying design considerations in the compositions of motifs and patterns of the monuments. In the context of the refurbishment of the early fragmented ornamentation of the Ahoms, it provides contextual information regarding the aesthetics, shapes, forms, and symmetry considerations of that era.

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Design and Development of Hand Tools for Metal Handicraft in Context of Adoption

Kiran Kumari Mahato and Pratul Chandra Kalita

Abstract The innovation of machine tools has had a major impact on productivity in the manufacturing industry. In design interventions on manufacturing equipment, craft adds value to productivity and quality. A major problem faced by artisans in the cottage handicrafts industry is the adoption of technology so as to maintain competitiveness in the global market. There are some barriers to the adoption of advanced technology—lack of access to technical information, unavailability of technically qualified persons to operate the new technology. This research has been done to fill the technology gap in the cottage handicrafts sector through the design and development of appropriate equipment. Currently the tools have evolved from blending the expertise and experience of artisans with modern technology. Survey of Assam State Brass Metal Handicrafts sector of India has been considered for this research study. This includes the study of relevant information through direct demonstration of work performance, equipment, work posture and environment, advice from skilled artisans. The process design set up for the devices is safe and easy to operate and increases productivity time and cost in the long run.

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Keywords Brass metal handicrafts · Design intervention · Hand tools · Production · Productivity · Operation management

1 Introduction

Handicrafts are a crucial medium to preserve rich traditional art, heritage, and culture, traditional skills, and talents, which are associated with people's lifestyle and history. India's rich cultural diversity and heritage provide a unique and spacious resource for developing craft products [1]. Since 1991 the concept of globalization of India

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has given rise to new opportunities for handicraft sector. The production of handicrafts has become an important part of the industrialisation process in rural and urban areas in the developing world [2, 3]. The urban industry occupied a very favourable and important position in India's economic activity. In spite of this we are confronted with the problem of rapid decline both in the artistic excellence and economic importance of these handicrafts [4]. Cottage industries are disappearing despite the huge demand for Indian crafts in the international market. Unfortunately, traditional handicraft industries are at risk of deterioration due to competition from cheaper machine-made alternatives [5]. Most of the developing countries still rely on traditional methods for their work. Modern technologies are of little or no use in these environments. These tools have often poured out too complex, too expensive, unsuitable, and arduous to implement. As a result, they are facing difficulties like domestic competition with machine-made products [6, 7]. Conventional industrial development tools and the new proposals of digital and technological facilitators have great potential to optimize the crafts system without compromising their identity values. But technologies incursion has still considered by artisan as disturbing elements of their procedures. This increases unwillingness to adapt new technology [8].

2 Methodology

The study is conducted at Hajjo brass handicraft cottage industry Assam (India). The research adopted qualitative methods. Qualitative information has collected through, observation method to understand the existing manufacturing process and tools and machineries involved. Personal interview with the workers was carried out to study the problems associated with the existing process. Tools have been developed with optimization in mind. There is a survey to understand the opportunities in the current practice of tools in the current process flow and to suggest improvements. It led to improving productivity by reorganizing production processes and using possible tools. Also, process issues, work space issues, safety and risk issues have also been taken into consideration. It also utilizes secondary data sources obtained from journals articles, books, reports and other available documents.

3 Aim and Objective

The aim of this study, is the design and development of hand tools, by blending the expertise and experience of the artisans with current technology. It led these tools to be compatible with their current working principle and are easily adopted by the artisans.

The main objective of tool design is to reduce the overall cost of manufacture, increase the production rate, maintaining quality, reduce the cost of special tool, design tool be safe and easy to operate.

4 Overview of the Impact of Modern Equipment and Machines on Cottage Industries

India is one of the crucial suppliers of handicrafts to the world market. Indian handicraft products are highly demanded all over the world [9].

After the Industrial Revolution, the popularity of technology developed rapidly. In this fast-paced modern life, people are dependent on machines to save time. Gradually, because of people's dependence on machinery, creativity is getting limited to that extent [10]. Which has had a direct impact on the lives of many skilled artisans. The main reason for this is that the cottage handicrafts industry is still dependent on traditional tools and techniques, which has brought the region to a standstill. This has led to a difference between the demand for the actual product and the actual product produced [5]. This has not only created a demand and supply gap but has also created a huge price gap between handmade and machine-made crafts. To reduce this price difference between machine-made crafts, it is necessary to improve the productivity of cottage handicraft industries. So that artisan can sustain a quality life. Sustainable development of handicrafts is given effect through technological interventions. It plays a vital role in the sustainable development of the people involved in the handicrafts sector [1].

4.1 Case Studies of Design Intervention on Crafts Field to Improve the Productivity

If Malay crafts are shed light on, Labu Seong, also known as Pinched Pottery, is one of Malaysia's pottery heritage. Along with hand-pinching techniques, some traditional tools practiced making artisan pottery. The equipment has advanced through cast casting techniques. Apart from retaining old methods in technology, modernization has also contributed to the aspect of scientific and applied equipment. The technology used indirectly contributes to more efficient construction processes and design techniques that will increase the productivity of traditional pottery [11].

A simple term for handicrafts given by the development commissioner (handicrafts) in 1989: "items made by hand, often with the use of simple tools [12]. Tools, Small technologies, and Design play a significant role in the repositioning of Craft. In the study of Tools, Small Technologies and Design for Bamboo Craft: Indian, a tool kit with 33 items and four small machines have developed at Bamboo

Studio, I.D.C. (Industrial Design Centre) under a U.N.D.P. (United Nations Development Programme) project on Bamboo and Cane. These machines are easy to operate, even that uneducated people can manage them. Productivity and quality have also increased due to these machines [13]. Similarly, In Sri Lanka, enhancement of productivity of the traditional brass manufacturing industry has been done using sustainable manufacturing concepts [14].

4.2 Field Survey

The Government of India has implemented some schemes during various five-year plans for the overall development of handicrafts. These include the Design and Technology Upgradation Scheme and the Babasaheb Ambedkar Handicrafts Development Scheme. The objective of this scheme is the sustainable development of handicrafts through the participation of artisans. This scheme has transacted through technical interventions and modern tools for manufacturing growth in the work area [15]. If the cast light on the brass industry of Moradabad, India, which alone accounts for 40 percent of the metal craft exports. Time study analysis and process flow analysis have transacted to enhance the competitiveness of the Moradabad Handicraft Manufacturing Unit. Based on the observation, the organization redesigns its manufacturing and support resources to facilitate the smooth flow of products [16].

Handicraft marks one of the most resistant cultures for technological implementation in the current post-industrial world. Although technology might improve the craft marketplace and its financial impacts, it might destroy these particular ways of cultural understanding, skills, national emotions, and expressionism. Technology, then, should be integrated within limits in the handicraft-making process. The study should focus on exploring these limits and technological implementations [17].

Surveyed the brass metal handicraft sector of Assam Hajo to understand the opportunities in the current practice of tools in the current process flow and suggest improvements. There are many issues and problems related to the tools and techniques used in the erection of metal handicraft items listed as:

Unawareness with modern technology: There have been some attempts at design interventions in technology before. But tools are in idle condition due to a lack of technical knowledge.

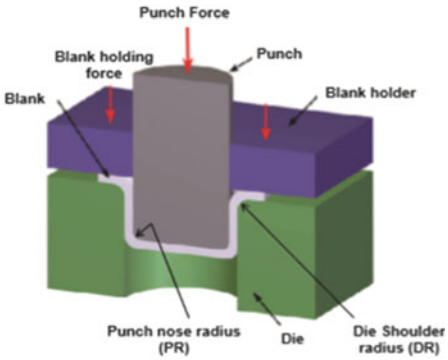
Lack of Education: Lack of technical education due to which the artisans could not solve the technical problem encountered during the operation.

Interruption in work flow: Intervened tools affected the craft but also disrupted the production process. As a result, the devices are idle shown in Fig. 1.

Lack of proper foundation: Some devices are active, but they have also faced some problems, such as a lack of proper machine foundations that cause vibration on the machine that affects finishing tasks.

Dependence on electricity: Dependence on electricity is also a problem for adopting new tools or technology.

(a)



(b)

Fig. 1 a Tool based on punch die concept (in passive condition), **b** concept of punch and die. *Sources* file:///G:/sheet_metal/04_chapter%201.pdf

4.3 Observation and Research Gap

In design interventions on construction equipment, craft adds value to productivity and quality. But the lack of technical skills has been seen as a hindrance in the use of modern technology. A major problem faced by artisans in the cottage handicrafts industry is the adoption of technology so as to maintain competitiveness in the global market.

According National commission for enterprises in the unorganized sector government of India, technology alone is not sufficient to improve productivity and efficiency of the unorganised sector. It requires the supply of other inputs as well particularly credit, raw material and skilled work force [18]. Artisans are always known for their skills, yet they face problems in upgrading their skills. If we look at our history, the handicrafts industry has never disintegrated despite the influence of every era, dynasty and empire. Rather a lot of new crossovers have been made [19]. Therefore, instead of upgrading the skills of the artisans according to the new technology, the new technique should be based on the skill and experience of the artisans. This will

help to make the work easier and at the same time, if there is any problem during the work, then the artisans can easily solve it.

5 Design and Development of Hand Tools

In the survey, it has been observed that brass metal sheets have been used for crafting. The thickness of the sheet is approximately 10–24 gauge. Sheets are cut into various shapes and are used to bend or roll metal sheets with the help of wooden dye and hammers. The basic steps involve in craft manufacturing and the working environment of craft industry can be understanding by Figs. 2 and 3.

Detailed study of the various shapes, forms and patterns of metal crafts, it is observed that brass crafts are manufactured with the process of making. In metal forming, the material is deformed plastically to take the shape of the geometry. Die and punch are used for such deformation. After analyzing the various tools used for metal manufacturing processes in the technology sector, roller dies are

Fig. 2 Cut sheets are curved or cylindrical bended

Fig. 3 Work floor of brass metal crafting

Fig. 4 Roller dies tool to bend sharp edge

found to be an appropriate tool in place of traditional tools for making brass metal crafts. The usefulness of tool is always questionable, if cost of tool is more than the save in production [20]. Basic design consideration for the tool has cost efficient, affordability, ease of use, volume flexibility and space constraint.

The first roller dies tool has developed to bend and rotate the sharp edges of the craft, as shown in Fig. 4.

Further manually operated, three roller bending tool has developed to meet basic shapes and forms produced during craft work. Roller bending has a continuous bending operation in which a long strip of metal has passed through consecutive sets of rolls, or stands, each performing only an incremental part of the bend, until the desired cross-section profile has obtained. Rolls have also used to joining the sheets [21]. After Bending operation of sheet, cavity has created inside the surface of bend part as per requirement through the shaping roller die (Figs. 5 and 6).

We need a reasonable amount of force to bend a sheet. The devices are designed through force analysis and the shape of the roller is chosen. Some anthropometric parameters such as popliteal, waist, mid-thigh to thigh width (rest), elbow rest, arm width without thumb on the metacarpal, grip inside the die maxim have also been considered for the design.

Through design intervention or through sustainable development of tools, productivity and quality can have increased. Through this they can be competitive with market. From survey it has observed that artisans are ready to use or adopt new tools. But for adaptation of new tools, reliable, less space required, easy to use, safe, easy to maintenance, no need of extra technical learning has considered in design and development of tools.

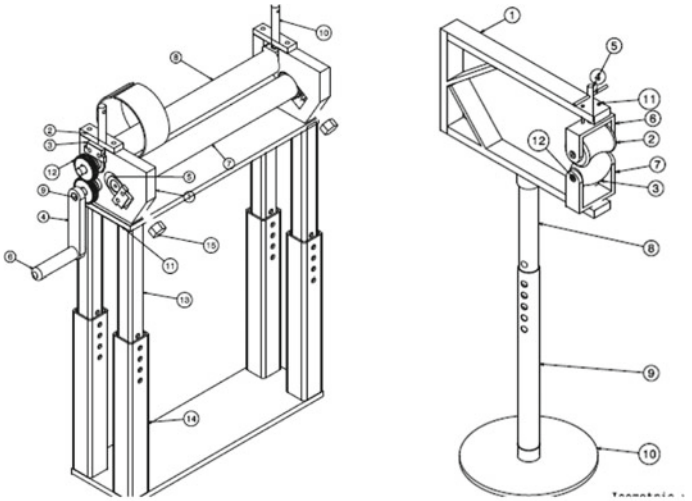


Fig. 5 **a** Roller die sheet bending tool, **b** roller die shaping tool

Fig. 6 **a** Prototype of sheet bending tool, **b** prototype of shaping tool

5.1 Productivity Analysis of Tools

Bending and cavity formation

To bend a sheet into 200 mm die and cavity forming, it takes 15 min. 3–4 persons involved in this work. Through the intervened tools its takes up to 4–5 min by one person. It increases the production rate (Fig. 7).

Complete product manufacturing includes main steps: cutting, bending and cavity-forming, and joining. Work is underway on time analysis throughout product manufacturing to assess overall productivity. Also, it discovered some modifications in the tool.

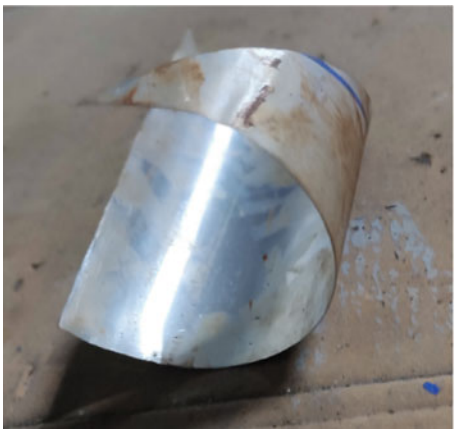


Fig. 7 Images of bend sheet and shaping operation of sheet respectively

Beading of sharp edges

Early edges are left mostly opened since it takes more time. Intervened tool (Fig. 4) takes up to 2–3 min to curl the edges. It also improved the quality of the product.

5.2 Cost Analysis

Material cost: The Assam government had started a mill for the supply of raw materials required under the MSME project. As the craft production rate is low, the inventory cost of raw materials increased. The mill had to be closed due to loss. The mills are likely to reopen with the increase in production rates. It reduces the cost of the product.

Craft cost: The increase in productivity will reduce the overall cost of the product.

Tools cost: Overall manufacturing cost of tools is approximately 1/4 of early designed tool (Fig. 1).

6 Conclusion

If we look at our history, the handicrafts industry has never disintegrated despite the influence of every era, dynasty and empire. Rather a lot of new crossovers have been made [19]. Therefore, instead of upgrading the skills of the artisans according to the new technology, the new technique should be based on the skill and experience of the artisans. This will help to make the work easier and at the same time, if there is any

problem during the work, then the artisans can easily solve it. This research has been done to fill the technology gap in the cottage handicrafts sector through the design and development of appropriate equipment. Currently the tools have evolved from blending the expertise and experience of artisans with modern technology. To bend a sheet into 200 mm die and cavity forming, it takes 15 min. 3–4 persons involved in this work. Through the intervened tools its takes up to 4–5 min by one person. Overall manufacturing cost of tools is approximately 1/4 of early designed tool. This has improved the productivity and quality of the product. Since the working principle of the new interference device is similar to traditional equipment, it has been adopted by artisans. further scope for new innovations can be made keeping in mind the technical skills, experience and technical process of the artisans.

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A Sustainable Approach for the Urban Sprawl of Kolkata (Circa 1690–2020)

Shilpi Chakraborty and Shiva Ji

Abstract Kolkata, hitherto known as Calcutta, till 2001, is the capital of West Bengal, India. Sutanuti, Kalikata, and Gobindapur were three villages that amalgamated today's town, which has a more than 300-year history and acted as the capital of British East India through 1911. Although one of India's oldest Heritage cities is developing in becoming the Smart City, the city has never designated planning policies. The Kolkata Municipal Corporation Authority (KMDA) was established in 1962, whereas the city's coalescence occurred in 1690, leading to an extended period of unplanned city growth. Asymmetrical urban sprawl evolved due to several factors, creating multiple challenges for the city and its inhabitants. As a result, an immediate requirement for examining the urbanization over time till the current scenario to formulate subsequent development plans would be sustainable. The implementation of remote sensing data and GIS helps to analyze data to provide sustainable design approaches. This paper addresses problems that contribute to urban sprawl while promoting sustainable design to mitigate the future's negative consequences. Urbanization and population growth, whereas the leading cause of urban sprawl, sustainable techniques provided would balance the heritage of past and future.

Keywords Heritage · Urban growth · Sustainable design · Planning policies · Smart City

1 Introduction

The major world's population is now the way of life is in an 'urban setting [1] Cities are widely regarded as hubs of more significant opportunity and competition, serving as the center of commerce and inclusive growth. Significant supervisory on financial and architectural development, land use mapping, facilities, and habitation

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are testing in India's metro cities. The central expenditure concavity for domestic and global participants in the country's remunerative development. India's urbanization, which many researchers ascribe to liberalization, privatization, and globalization, and the country's magnificent advancement after financial ameliorate in the 1990s, have posed a slew of challenges. When it comes to uniformly spreading growth around the country's diverse population, the emphasis is on the cities' long-term sustainability and inclusiveness. Metro cities are multi-municipal megacities that have grown significantly in vertical and horizontal dimensions over the last few decades.

As a result, the socio-cultural and commercial disparity among the affluent and the marginalized has developed over time. Cities' poverty-stricken have a restricted approach to collective and exclusive commodities and amenities, resulting in unequal and segregated resources. Kolkata is no anomaly to these laws of embargo urban growth and chronic contiguous indigence, which create and sustain a complex indigence trap that jeopardizes people's health, earning power, political participation, and overall wellbeing. In order to achieve equitable, sustainable, and inclusive growth in Kolkata, efficient conceptual frameworks are needed, according to SDG 11 [2]. The extent of suburban growth and urban sprawl is to quantify rapid urbanization. Globally, the development of models for analyzing and anticipating urban growth has utilizing remote sensing data and Geographic information system (GIS) outlook [3, 4]. The urban agglomerations in India have evolved rapidly, and India will have the world's highest congregation of metropolitan agglomerations by 2021. Kolkata is the tenth substantial urban built-up in the world [5]. Several studies have investigated urban growth and land metamorphosis in Kolkata [6, 7].

2 Literature Study of Kolkata: An Exordium

Kolkata, the authoritative capital of West Bengal in Eastern India, is the world's fourteenth biggest city and India's first urban entity. The metropolis runs north-southern axis across the Hooghly (Ganga) Riverbank on the eastern side in the eminent river delta Bengal depression, approximately 75 km west of the Bangladesh frontier. It is at latitude 22.5726° N and longitude 88.3639° E. The bulk of the soils are alluvial. A large portion of the town was once a wetland retrieved over time to harbor an increasing population. The East Kolkata Wetlands, the last unformed region, has been declared a "wetland of critical importance." The arrival of the East India Company for export in 1690 marks Kolkata's history.

Job Charnock, a Britisher, established the city with three villages: Sutanati, Kolkata, and Gobindapur in 1690. Kolkata (then Calcutta) was established as an East India Company commercial capital and acted as India's capital city until 1911 at the mercy of the British Raj. Since colonialism, Kolkata has held immense critical implications as the only central coalescence hub of commercial, political, and corporate activities and the intellectual and research pivot. The city's emergence as a center

Table 1 Population density of urban Kolkata during 1901–2011

Years	Population	Population growth	Population growth rate
1901	1,510,008		
1911	1,745,198	235 190	15.58
1921	1,884,584	139,386	7 0.99
1931	2,138,563	253,979	13.48
1941	3,621,413	1,482,850	69.34
1951	4,669,559	1 048 146	28.94
1961	5,983,669	1 314,110	28.14
1971	7,420,300	1,436,631	24.01
1981	9,194,018	1,773,718	23.9
1991	11,021,918	1 827,900	19.88
2001	13,205,697	2,183,779	19.81
201 1	14,112,536	906,839	7.6

Source Census India, 2011

of labor growth and financial opportunities drew simulated and real emigration for the next two decades, as seen in Table 1.

Some attempts to reallocate urbanization and industrialization and phases to other areas of the region, such as establishing suburban areas such as Asansol, Durgapur, and Siliguri, were made. However, this onslaught of migration went largely unnoticed, and Kolkata's longitudinal and transverse urban expansions intensified. The city's suburbs have seen an unexpected rise in built-up areas, resulting in infringement on agricultural land and the city's continued centrality [8]. Kolkata's existing land use characterization a high-density urban core and massive linear suburban development in the city's surrounding areas. The city has experienced ongoing rapid growth in various directions to meet the city's booming population and cultural and trade needs.

Because of the city's distinct socio-economic and political projections, Kolkata's growth rate course has been erratic across the years. In the former part of the twentieth century, the city had elevated population density, but this intensity declined significantly in the 1960s. The city center may have become concentrated in terms of occupants influx and accessible infrastructure, a condition compounded by the city's sluggish financial wellbeing; severe scarcity of necessary public infrastructure; and the per diem, together with severe land-use restrictions, all of which may have undermined the KMC's ability to endure itself. Furthermore, improved transit services have made daily transit more convenient, allowing people to move to house neighborhoods on the outskirts of cities where land and minimal housing are abundant, leading to the rapid growth of the periphery [9].

3 Methodology

"Urban sprawl" has a negative connotation, yet not all urban growth is terrible—some forms of urban growth act as a counterbalance to sprawl. For methodology, the study comprises a comparative analysis of several features of urban sprawl investigated through multiple papers. Measurement of Sprawl can be on both a quantitative and qualitative scale. In figure-ground concepts, absolute measures will distinguish between a vast metropolis and a compact city. The research investigates the use of remote sensing data and GIS tools to locate, track, and assess characteristic patterns, urban expansion dynamics, and sprawl on Kolkata terrain.

While the exact definition of urban sprawl is debatable, most accept characterization by a random and inconsistent development pattern induced by multiple procedures and resulting in inadequate resource usage—the territory's land-use changes as built-up and roadways increase [10]. Undoubtedly, not all genres of urban expansion are sprawl; growth can be contemplated as sprawl by one person but not by another. Furthermore, the word "urban sprawl" is pessimistic, and urban growth is not detrimental. Some types of urban development serve as antidotes to sprawl. As a result, the simplistic evaluation of "the sum of land that has changed to urban uses" cannot correctly characterize sprawl. Sprawl ought to be considered differently from urban growth in general.

Analysis of urban development as a trend and mechanism from remote sensing data aids in understanding how an urban environment changes over the period. This knowledge incorporates.

(1) the degree of urbanization,
(2) growth's comprehensive environment,
(3) if or not it has some discrepancy between measured and predicted acceleration,
(4) if there is some disparity in development through space or time, and
(5) If or not, the expansion is sprawling.

It is significant to note that scholars, policymakers, environmentalists, and the public have various perspectives on sprawl, and the absence of cooperation on ways to explicate the sprawl hinders endeavors from identifying and regulating this genre of land expansion. Table 2 shows several attempts by researchers to categorize the sprawl.

3.1 Evaluation of Sprawl

Measurement of Sprawl can be on both an objective and subjective scale. Absolute measures will tell the difference between a sprawling city and a condensed city in figure-ground terms. On the other hand, relative metrics compare several aspects of urban growth through cities, areas within a region, or time spans within a city. Until the latter case, the researcher can decide whether or not the city sprawled,

Table 2 Different factors of urban sprawl in India

	Built-Up Area	Community	Aesthetic	Disintegration	Usability	Density	Green Space	Mobility	Financial	Utility
Abhishek [11]	Yes				Yes	Yes			Yes	
Aithal [12]	Yes					Yes				
Bhatta [13]	Yes	Yes					Yes	Yes	Yes	Yes
das Chatterjee [14]		Yes			Yes					Yes
Das [15]				Yes			Yes			Yes
Diksha [16]		Yes	Yes		Yes	Yes			Yes	
Dutta [17]				Yes	Yes	Yes				
Jat [18]			Yes	Yes	Yes	Yes				
Krishnaveni [19]	Yes		Yes						Yes	
Kumar [20]	Yes					Yes	Yes	Yes		
Schneider [21]	Yes				Yes	Yes	Yes			
Sudhakara Reddy [22]	Yes				Yes	Yes				
Taubenböck [23]	Yes				Yes	Yes				

Source Author

or he or she can choose not to describe the sprawl. It is significant to note that most sprawl evaluation approaches use relative measures or combinations of urban planning metrics as sprawl indicators. With these steps, it will never recognize sprawl except to determine a barrier regarding a figure-ground interpretation of sprawling and non-sprawling. Determining an approach, on the other hand, is a challenging task. To establish this threshold, researchers developed assumptions that are even smaller apparently to the scientists. It is important to note that most comparative sprawl or urban growth pattern implantation fails to achieve sprawl and cannot be universal. These measures may be helpful for analysis, but the technology can never consider them since a scientist must interpret the results.

Remote sensing data and geographic information system (GIS) techniques for urban density, land-use development, and sprawl planning (to contemplate the urban influence), imprinting (to apprehend the urban development procedure), evaluating (to scrutinize), and progress of the modeling over the years (to revitalize). Remote sensing data and GIS techniques to identify, chart, and evaluate physical manifestations, urban growth trends, and sprawl on topography. Studies have suggested many metrics and figures that have mainly applied to cities in developed countries throughout the last two decades. While several of these criteria can quantify various aspects of urban development on a comparative scale, they fall short of monitoring and assessing urbanization on universal scales that can be analyzed and evaluated in figure-ground terms. In order to explain population development and sprawl, researchers used a variety of metrics and scales [13].

Moreover, while these frameworks can contribute a deeper understanding of urban growth, they often require many inputs to generate the concluding outcome. Cities in developed countries may have adequate planning legislation for cities, but cities in the 3rd world disregard such legislation and grow with total independence in the vast majority of cases. Several frameworks mentioned above, which have been created and praised by the global community, mainly target developed countries. As a result, the advantages of such a framework for cities in developing countries seem to be much little convincing.

Moreover, in developed countries, city authorities are often unfamiliar with modern technology. In addition, city managers in developing countries are often inexperienced with approaches or methods and advanced technologies such as geospatial techniques. As a consequence, they require analytical methods with a limited set of processed information. The establishment of the Kolkata Municipal Development Authority in 1962 resulted in organized planning for the city (Figs. 1 and 2).

Since 1975, the northern-central areas have had a severe agglomeration of built-up areas, with a marginal growth rate due to built-up impregnation. The southern area's extension, followed by the eastern area's, is highly worrying. Between 1990 and 2000, the built-up area grew at an astounding rate of 16.6%, and between 2000 and 2015, it increased by a percent. The majority of the groups declined in their respective areas. According to the same survey, two land-use categories, rural areas and open, have deteriorated in their respective areas. The urban secondary core area rose by 30.6% between 1990 and 2000 and 35.4% between 2000 and 2015. Between 1990 and 2000, the primary urban center expanded by 21%, and between 2000 and

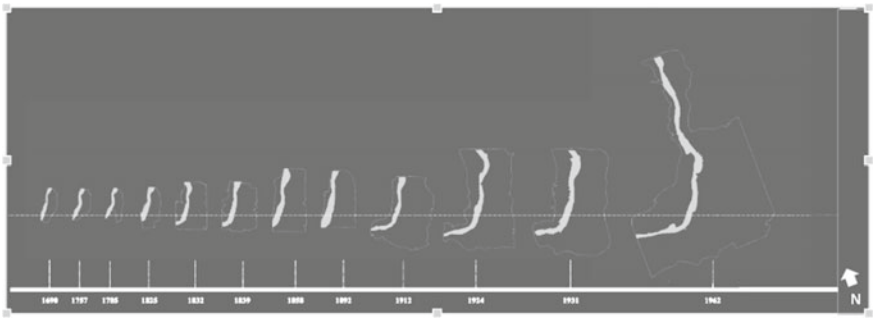

Fig. 1 Mapping of evolution of urban sprawl of Kolkata (1690–1962). *Source* Author

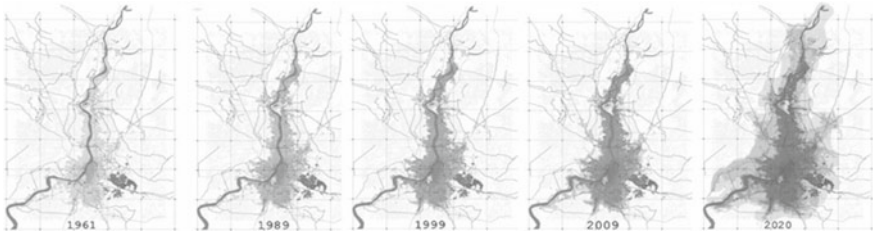

Fig. 2 Mapping of the evolution of Urban Sprawl of Kolkata (1962–2020). *Source* adapted and modified by Author

2015, it expanded by 36.2%. The suburban fringe grew by 12.8% between 1990 and 2000 and 19.9% between 2000 and 2015. The scatter aggregate by 14.9% between 1990 and 2000 and 19.6% between 2000 and 2015, as shown in Figs. 3 and 4.

4 Result

According to the study, Kolkata is experiencing rapid urbanization, loss of vegetation, agricultural lands, and wetland areas. As a result of these land-use changes, there are more built-up areas and fewer open spaces. The ecosystem would gradually deteriorate in greenness, moisture status, built-up density, and surface temperatures. The disruption occurs in the physical features of the city's surface by changes in the city's temperature profile. This reaction alters other biophysical parameters, causing the fragile ecological equilibrium causing disruption leading to more severe issues such as shifting rainfall patterns and intensities, endangered biodiversity.

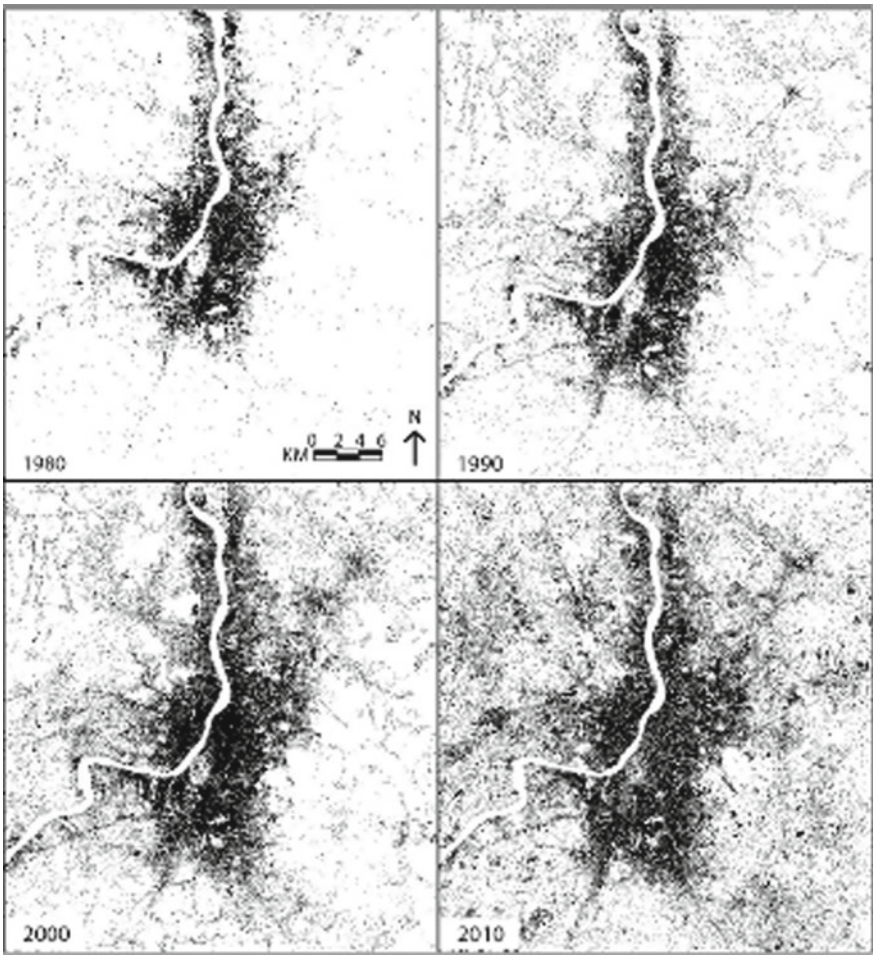

Fig. 3 Built-up growth in the Kolkata metropolitan (1980–2010). *Source* Fazal (2013)

4.1 Implementing the Findings

The results of the research predict the extent of the change that will arise if current trends continue. Suppose historical and current course in built-up development prevails over the next thirty years, the percentage escalation in the infrastructure to determine the intensity of urban growth that this city to develop while also offering indicators. Although numerous factors ignore previous and current urban growth trends to develop for cities' inexorable subsequent density, this strategy eventually concludes in insufficient or even marginal urban growth planning on both the activist and authoritative grounds. It is unquestionably inadequate, unequal, and wasteful, imposing severe environmental damage on societies unable to afford them.

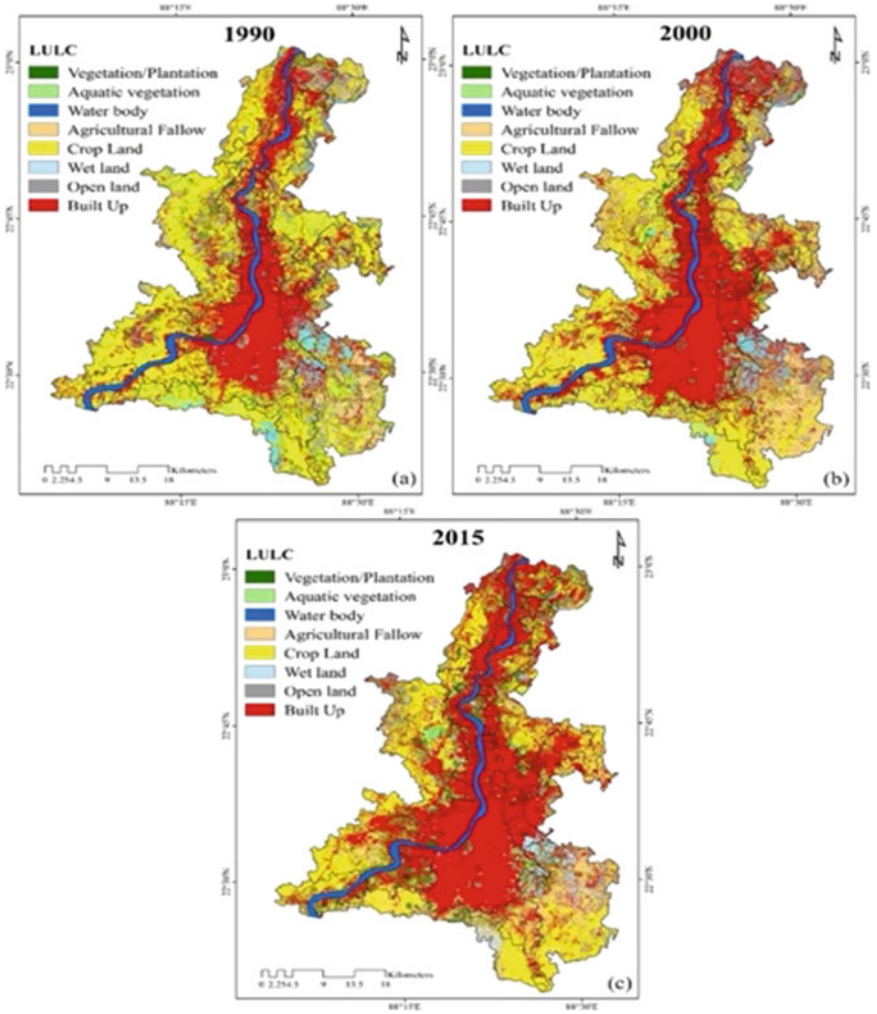

Fig. 4 Kolkata UA's land use/land cover map (1990, 2000 and 2015) (Rahaman et al. 2018)

This study employs remote sensing/GIS techniques to investigate the background and comprehend the current, illustrating numerous methods/models that result in potential planning. Comprehension of previous and current urban growth trends helps with some of the tools to address them in the decades ahead in a realistic, equitable, and responsible way.

5 Urban Sprawl and Sustainability

There is evidence that there are positive associations between urban growth and sustainability [24, 25]. Scattered urbanization has contributed to environmental deterioration, high energy usage for infrastructure, and pollution [26]. The establishment of the compact urban idea is in response. There is a need for a more precise picture of the explanatory interconnection linking urban growth patterns and sustainable development. Seeking empirical data on the sustainability impact of urban growth trends via a cumulative study of urban areas with various urban growth patterns over time can help recognize the advantages and disadvantages of each multiple urban growth trend in terms of sustainability, as well as the factors influencing such a system, thus assisting in the incorporation of sustainability concerns into the planning process.

Cities employ various legislative proposals and approaches to boost sustainability by addressing financial, societal, and global impacts and regularly evaluating the viability of policies and legislation from sustainability and other sustainability issues into strategic planning. Moreover, a wide variety of stakeholders, comprising regional, state, and federal governments, nonprofit organizations, individuals, and non-governmental organizations, are involved in pursuing sustainability (NGOs). Encouragement of cooperation amongst numerous participants should be a core pillar of urban sustainability management in this regard.

5.1 Indicators of Sustainable Development: Their Objectives

Indicators are tools for evaluating progress toward a goal or the effectiveness of a strategy or plan. Sustainable development metrics track the state of an economy's fiscal, environmental, and social systems to determine if policies, strategies, and initiatives are having the desired impact. Indicators are tools for evaluating progress toward a goal or the effectiveness of a strategy or plan. Sustainable development metrics track the state of an economy's fiscal, environmental, and social systems to determine if policies, strategies, and initiatives are having the desired impact (Miller, n.d.). Indicators for sustainable development help prepare, clarify policy goals and priorities, budget, engaging with the public, and evaluating results. Metrics for sustainable development raise awareness of the interconnections and exchanges among the three pillars of sustainable development (financial, ecological, and societal aspects) and the long-term consequences of current decisions and behaviors [27]. One of the most challenging aspects of environmental management is handling various ecosystem services in a cityscape. It is critical to evaluate services at multiple scales—space and time, particularly at the regional level—and comprehend human behavior feedback loops to respond to rapid urban change. Indicators are an essential part of the overall measurement of progress in sustainable growth, and they have received much attention in recent years. A learning process incorporating best practices for a stakeholder-led local sustainability evaluation system is one of the several

analytical approaches suggested to improve sustainability metrics at a local scale. Analyzing rural–urban areas in terms of specially established indicator structures to researching such complex socio-ecological systems is necessary.

The current indicators are evaluated and modified in this analysis for sustainability goals [28] with the help of remote sensing data gathered for Kolkata [13, 29–31] and the establishment of a conclusive last array of indicators on data affinity and consistency. The following are the eight types of sustainability metrics used in this

Table 3 Urban sustainability indicators

Classification	Indicator	Correlation to sustainability
Population	The intensity of population growth	−
	The density of the population	
Land use	Agricultural zone	+
	Forest zone	
	Green belt	
Transport infrastructure	Car ownership percentage	−
	Non-vehicle user percentage	+
	Car user percentage	−
	The length of time traveling	−
Health and wellbeing	Crime incidents per thousand population	−
	Fire incidents per thousand population	−
	Safe drinking water inhabitants	+
	Sewage disposal facilities	+
	Hospitals per thousand population	+
Housing and education	Dwelling units per 100 households	+
	Proprietor rate	+
	Literacy rate	+
	Student–teacher ratio	−
Environment	Waste generation	−
	Waste recycling rate	+
	Water consumption	−

(continued)

Table 3 (continued)

Classification	Indicator	Correlation to sustainability
	Energy consumption	−
	Air pollution amenities/10,000 person	−
	Water pollution amenities/10,000 person	−
	Synthetic chemicals usage	−
Economic system	GDP	+
	BPL/1000 inhabitant	−
	Work equality for citizens	+
	Employment rate	+
	Occupation heterogeneousness	−
	Financial independence	+
Community engagement	Percent of (NGOs) per 10,000 people	+
	Voter turnout	+
	Average capita annual library attendance	+

Source Author

study: Housing and education; population; land use; transport infrastructure; health and wellbeing; environment; economic system; and community engagement. The relationship between each indicator and urban sustainability is in Table 3. The plus sign stipulates that the elevated the amount, the good the sustainability relationship. The higher the amount, the more negative the relationship to sustainability is.

6 Conclusion

In Kolkata, the intensity of urban growth is usually due to rapid population and household growth. The rate of sprawling, on the other hand, is gradually reducing. It is important to note that Kolkata is not getting more condensed as growth in population slows as an emerging country's metropolis. These results assure the city's climate-related sustainability; however, limiting the city's sprawl may be essential (because generally, sprawl imperils sustainability). It was discovered by analyzing

the significant indicators of Kolkata city among the eight different criteria that policymakers should regulate or govern these indicators to turn Kolkata into a Smart city. It will result in the city's long-term growth. The approaches employed in the study will provide an outlook on the development of smart cities—the extension of the technique to a variety of small and medium-sized towns.

Several current metrics for analyzing urban development and sprawl have been evaluated and validated in this study. Most existing analytics findings are particularly reliant on temporal image resolution, and they often measure complementary attributes. Several of hods necessitate a massive amount of data and estimation, and their results can differ significantly.

6.1 Limitations

Using Kolkata remote sensing data, this indagation attempted to scrutinize the effect of urban growth and progress on sustainability. They vary from other municipalities in terms of physical features, government policies, and economic foundations. As a result, generalizing research results to municipalities in other metropolitan regions can be difficult. As a result, more empirical data would need to be gathered by looking at other events in different situations.

Due to the scarcity of data, this study relied on 35 sustainability indicators. The term "urban sustainability" refers to an extension of city features. Consequently, research focused on more sustainability metrics will provide more reliable and informative information on progress toward sustainability.

6.2 The **P***urview of Future Research*

The findings of this research could pique the fascination of some researchers who wish to establish a practical framework for determining relationships interrelation linking the causes of urban sprawl and the analysis of this study. The ramification of such acceleration in Kolkata could be the focus of future studies. The studies lysis of the environmental and socio-economic impact of urban growth and urban expansion in Kolkata will provide a fascinating glimpse of urbanization and prepare for a more sustainable future. During the reporting period, analysis has already started to structure the dynamics involving urban growth and its determinants.

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Oro White Toothbrush | Design and Conceptualizing Dental Caries Detection Method

Bitopan Kalita and Ashish Sharma

Abstract We are living in a world today where stopping or halting can cause tremendous loss to our society. We have learned this lesson in the pandemic of COVID-19 the hard way. But a pandemic is not only the reason that can cause a halt. Toothache pain is described as intense, throbbing, miserable, or unbearable as it can affect a person's ability to perform normal activities such as job, social activities, housework, talking, sleeping, and eating, all of these factors can result in mental health problems and halting their everyday life. In this particular design intervention, a device and a mobile application have been conceptualized as a solution, which will help common people to detect potential dental caries and will be able to take precautions. The device is a toothbrush specially designed and conceptualised that can detect tooth enamel decay. This data will be analysed in the mobile application to inform the user about their dental health.

Keywords Product design · Ergonomics · Medical product · Dental care

1 Introduction

Toothache is a problem humankind has been facing since an early age. Various anthropology studies were conducted over fossilised human remains and these studies reflect conclusions that human dental health is noticeably different from other vertebrae on earth, also termed as not normal [1]. Other vertebrae on earth do not suffer from cavities as we do, but upon comparison, the early human had fewer problems than today's evolved Homosapien [1]. Evolution has been termed as the reason behind the state of dental health that human beings have today. Studies suggest that as humans started eating different kinds of food (from soft to hard) our teeth evolved in the same way, making them both hard and tough. Hard can be defined as the ability to resist any break or crack and toughness can be defined as the ability to resist any spread of break or crack. Hence we have two parts in a tooth, the enamel, which is

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entirely made of calcium phosphate responsible for making the tooth hard whereas the dentin, made of organic fibre makes it tough and flexible. Enamel is created by a special type of cell called Ameloblasts which grows outward, on the other hand, dentin is created by Odontoblasts which grows inwards. Once the enamel is created it can not be reproduced again, although dentin can still grow and maintain itself.

The enamel of the human tooth is prone to decay, the reason behind it has been discovered as microbes living in the mouth. Specifically, Streptococcus Mutant, Streptococcus Sobrinus and Lactobacillus are considered to be responsible for the decay of enamel [2]. Whenever a person eats food, food particles get stuck in their teeth. These microbes immediately start breaking down the starch and sugar in the stuck food particle and the process they release acids. These acids can destroy the teeth enamel. The wounded enamel surface contains two parts, dental cavity and dental plaque. Dental plaque is nothing but a sticky thin film of microbes, this film surrounds the cavity created by the microbes. Furthermore, throughout life, these decays (also known as demineralization) get repaired or remineralized by the minerals in the saliva (Calcium, Phosphate and external Fluoride) and if the rate of demineralization is more than the rate of remineralization the cavity becomes irreversible.

This dental caries or cavity or decayed enamel can cause pain and sensitivity in the affected tooth, as the pain receptors and nerves are exposed after the enamel layer is destroyed. The pain and sensitivity can affect a person's day to day life both physically and mentally.

In this particular design intervention, a consumer-grade toothbrush and a mobile application have been conceptualised and prototyped (for user testing). This sensor-based approach will help predict potential demineralization in tooth enamel and warn the user with the help of the application.

2 Literature Study

2.1 Area of Research

The study conducted primarily focused on finding a solution that can warn a person about an ongoing decay process of enamel in the teeth. Heuristics interviews with dental care specialists helped to realize that caries can be prevented if detected early; most of the patients are generally too late when they come for a dentist consultation. Experts also informed that during the inspection of one complaining tooth decay, much more decay in different teeth gets discovered that helps the patient to prevent the tentative cavities. Dentists generally use non-invasive methods such as visual-tactile, Quantitative Light-induced Fluorescence (QLF), Fibre-optic Transillumination (FOTI), DIAGNOdent (DD) and Electrical Conductance (EC) [3–5] for dental caries lesion detection. Our study focuses on using one of these techniques to develop a product that can detect early caries lesions and warn the user of the product.

2.2 Related Work

Dentists generally use different medical-grade types of equipment for the diagnosis of caries but for a consumer-grade product, the sophistication of the medical-grade types of equipment must be avoided. Extensive market research was conducted to understand the existing products in the market. As a conclusion of the market research, we found currently available electric toothbrushes provide the following functionalities in comparison to a manual toothbrush.

- Non-corrosive and recommended brush movements
- Ease of cleaning
- Product lifetime
- Monitoring brushing habits.

This is important as improper brushing techniques can cause damage to the enamel [6]. Currently, only a few products are available for consumers for the highest dental health care options.

The secondary literature review helped to identify a very commonly practised non-invasive method to detect dental caries. This method describes using alternating current in fixed frequency to measure the resistivity of tooth enamel [7]. This method has been in use since 1950 and it started in the United Kingdom [7]. Later a device in early 1970 that uses fixed frequencies to monitor and detect caries called "Vanguard" was in common practice in the US [8], 1980 along with a Japanese cavity detection device called "Caries Meter L" [9] was introduced and was performing effectively [10]. In 1996 for the first time, multiple electrical frequencies were used by a method called "AC Impedance Spectroscopy Technique (ACIST)" to detect dental caries in a controlled environment [11]. This use of multiple frequencies helped characterise healthy and enamel under the process of decay [12].

This concept of using multiple electrical frequencies with the method of ACIST has reshaped itself as a smaller device called "CarieScan Pro", developed by a Scottish company named "CarieScan". After a clinical trial, the accuracy of the device in the detection of dental caries has been considered uncompromising. The device uses different frequencies of electricity on the tooth and measures the resistance, this data can be analysed and caries can be detected (Fig. 1).

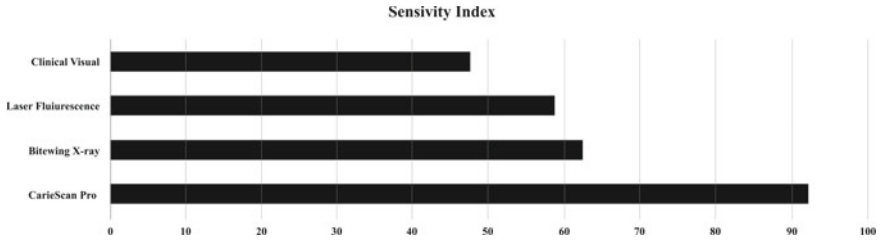

Fig. 1 Sensitivity index (rate of accuracy) comparison among different methods of cavity detection [13–15]

2.3 Dental Care in Human Behaviour

Humankind has been considered the most intelligent living being on earth, this comes from the ability to learn, use logic and make complex decisions. Humans do daily tasks as behavioural habits, such as taking care of hygiene. These behavioural habits are the results of genetics or newly learned habits [16]. Studies have shown that it might take up to 254 days to build a new habit [17]. There has been evidence from ancient Egypt in 3000 BC that people used to brush their teeth as well as practise dentistry in 2660 BC [18]. In time with globalization, the habit of brushing teeth got popular and across the globe, people have adapted to this habit and considered it to be one of the most popular behavioural habits among humans. Brushing teeth was widely adopted, as the skill of agriculture developed and humans started having more sugar and fat in their diet and brushing off the food particles from the mouth started as an act of prevention from oral issues, that can occur when microbes start breaking the food particle which in the process can damage the enamel.

Dental care is a long term investment, a person may not see immediate results. Hence the idea of a new consumer product being deployed in the market may not work very well as using that device will require a new daily habit. Therefore, the detection method has to be melded in an existing habit, such as brushing teeth.

3 Process

3.1 Methodology

The methodology for arriving at a point of agreement with the most suitable solution started with asking the 5Ws (What, Where, When, Why and Who). We wanted a well-known habit to be technologically advanced enough to warn a person about the hidden dental caries. Caries can cause physical pain and psychological discomfort that can hamper an individual's productivity [19], as the proverb goes: prevention is better than cure, we wanted to design a product to prevent such events of discomfort. We live in a time where technology has made our daily lives autonomous in many ways. Autonomous data collection with user consent can help to build better products.

We started with qualitative user research to understand the habit of dental care in human behaviour. 9 participants staying with family, 15 participants staying away from family/living alone were part of the study. The demographics of the participants were based on a relationship between habit formation and the influence of surroundings [20]. The participants were asked about their daily oral health care routine and any particular device/app they use to aid oral health care, the findings helped us to decide the goals.

Primary Goal. All the participants shared one common habit of brushing teeth daily (once or twice). Therefore, we decided to design a toothbrush that can collect

information about tooth enamel health while brushing and feed this data into a mobile application to analyse and visualise the information.

Secondary Goal. With the consent of the user, this data can be collected and by using machine learning this data can be trained for more accurate diagnosis.

The solution is the combination of two products, first an ergonomic toothbrush and secondly a mobile application to analyze the data collected from the toothbrush. For the development of both the products different methods were used. For the toothbrush, we collected information from the research participants in one to one interviews. This step helped us find a form for the toothbrush. Secondly, for the mobile application, we started with competitive analysis, user research, and affinity analysis to decide the hierarchy of functionality of the application.

3.2 The Oro White Toothbrush

Form of the toothbrush. As the first step, we tried to understand how people hold the toothbrush. Participants were chosen on the basis of the 95th percentile [21] (adult male and female) for designing the ergonomic grip of the toothbrush. Ten participants range from 90 to 95th percentile which provides a good overview of the population of India. As a process, we asked them to consider four different sizes of cylindrical rods as a toothbrush and observed how they held the brushes (Table 1).

As a part of this research, the participants were asked to choose one cylinder which according to them was more comforting and easy in mobility. Once we had the preference we moved to the second step, finding the most ergonomic form for the toothbrush. We observed that 80% of the participants held the toothbrush in their hand as shown in Fig. 2a and participants gave cylinder 3 the highest rate of comfort.

Table 1 Diameter of cylinders used to observe holding practice of toothbrush

	Cylinder 1 (cm)	Cylinder 2 (cm)	Cylinder 3 (cm)	Cylinder 4 (cm)
Diameter	0.8	1.5	3	4

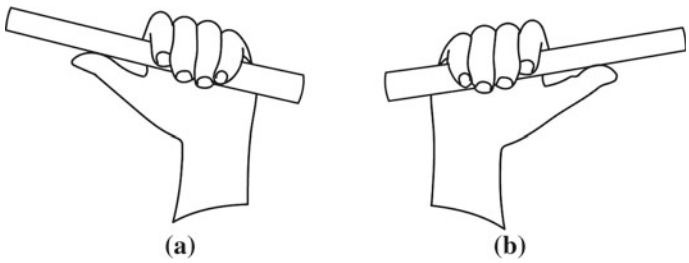

Fig. 2 **a** Holding posture in right hand, **b** Holding posture in the left hand

Table 2 Sample data of measurements from the research on the toothbrush handle form

	Distance from palm base to the tip of			Concave palm
	Index finger (cm)	Middle finger (cm)	Pinky finger (cm)	
Participant 1	16.9	18.7	14.4	Yes
Participant 2	15.8	17.4	14.1	Yes
Participant 3	16.8	18.7	14.7	No (Flat)
Participant 4	14. 5	16.6	14.3	Yes

Therefore, considering preferred holding practice as Fig. 2a and comfort around 3 cm diameter, we started taking measurements of the hand palm of the research participants (Table 2). These measurements helped us conceptualize and visualize the form of the toothbrush handle.

These distances from the palm base to the tip of the index finger, middle finger and pinky finger gave us the measurements using which we found the mean value in each case (Fig. 3a). These mean values helped us to visualize the initial form of the toothbrush (Fig. 3b). Taking consideration of the concave section in our palm [22], the hollow section was complemented with a concave bulge in the form of the toothbrush (Fig. 3c).

Form & structure of upper section with bristles. After finalizing the form of the handle we started designing the upper section that will contain the bristles of the toothbrush. In this section, the sensors have to be included in the bristles so that while brushing teeth the soft electrodes [23] can touch the surface of the enamel to pass the alternating current in different frequencies. Multiple soft electrodes will be included for a better collection of data, also the fact that soft electrodes may get damaged after a long time of use. Therefore, the upper part of the toothbrush will be removable and replaceable (Fig. 4a, b).

The toothbrush will have functionalities such as motorized movements as an electric toothbrush, connectivity through Bluetooth, batteries and wireless charging

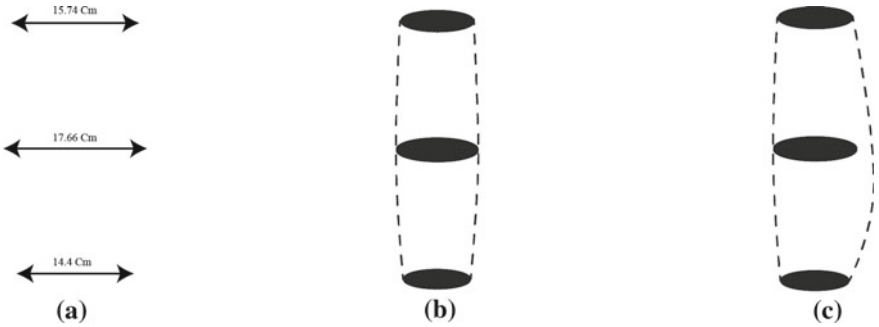

Fig. 3 **a** Mean value of the measurements, **b** Ideal shape based on measurements, **c** Added bulge to complement the concave curvature of a hand palm

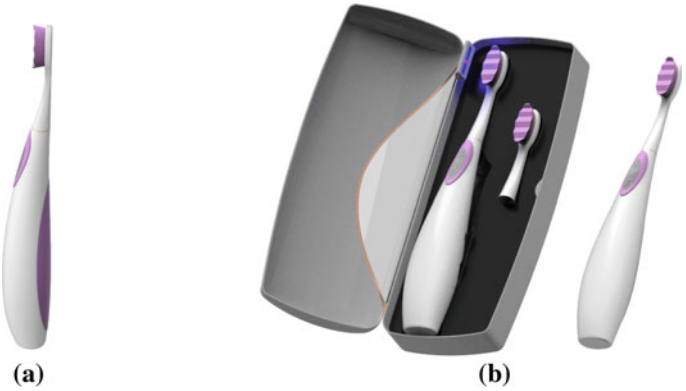

Fig. 4 **a** Side view of the toothbrush, **b** The toothbrush, the case & replaceable bristle

capabilities. The connectivity is important as the data collected by the soft electrodes has to be analysed to produce any information visualization.

An ultrasonic sensor has been ideated to be included which will help the sensors know on which tooth they are performing the data collection. This will help the users to know in which areas they might need to take care of.

Case to contain the toothbrush. Along with the toothbrush a portable charging case has been conceptualized. This case will be connected to the electricity through a wire and the case will charge the brush wirelessly when placed in it. Toothbrush bristles generally get wet which increases the chances of microbes taking over them, which is unhygienic. As a solution inside the case, a small unit of a UVB light will be installed so that when the brush is placed the UVB light can sanitize the bristles [24].

3.3 Oro White Mobile Application

The ideation of Oro White App. Once the data is collected from the toothbrush it is time to send it to the mobile application for the analysis part. A normal user might find it challenging to derive a conclusion from the raw information, therefore the mobile application will help the user visualize the data.

Considering the user experience a list of functionalities were prepared, to create the hierarchy of the functionalities both quantitative analysis and qualitative analysis was conducted. A survey among 30 research participants was conducted for quantitative user research where the participants were asked to choose the top 5 features for the toothbrush mobile application. As a result, we had the top 5 functions we needed to include among a long list of other functionalities. These functions are

- Decay Alert

- PH of mouth alert
- Brushing habit alert
- Call a dentist
- Habit builder.

That brought us to the qualitative research section, a meeting was arranged with two working dentists to understand what will be more beneficial for the users among the 5 selected functionalities. Although including PH value was not initially planned, the doctors explained why that would add a valuable function. The lower the PH value, the more acidic a mouth is, and acid is directly responsible for the decay in enamel. Informing a user about their PH values can save them from potential damage and bad breath.

The journey of Oro White App. Once a user signs in they will be able to pair the toothbrush with the mobile application. This connection will be BlueTooth based. Once the user will brush with the toothbrush, the data will be transferred autonomously. Once the data is in the application it will be analysed based on resistivity recorded in different frequencies and it will be able to conclude a result of the data analysis.

As the position of the teeth will be known hence the interface will have a graphical image of the upper and lower teeth, where depending on the position of the alert will be presented. This is to make the application experience more personalized. The alert will contain detailed information on decay, generally presented as the percentage of decay compared to a healthy tooth. On top of that as an overview, various alerts are colour coded so that the user will know the importance of the alert.

There will be the PH value on the first homepage, the decay alerts, saved dentist information, and a habit-building tool. In the PH section, the user will have the PH value of their mouth. After user testing, it was realized that not everyone is aware of what PH is, hence an elaborate simple explanation is provided along with the PH value so that a user can understand what a PH value signifies for their oral health. A user will be able to save their communication of dentists details in the application, which will be beneficial to contact in need and sharing information collected by the toothbrush for doctor's consultation. The habit building tool is conceptualized to build healthy habits among people for better oral health, encouraging users to brush teeth, eating healthy food for oral wellness is the goal of this functionality. The application keeps track of these habits/data and lets the user see their performance over a period.

The application also keeps track of the overall health of the toothbrush itself. Soft electrodes [24] might get damaged over time, hence keeping track of the upper replaceable section of the Oro White toothbrush is necessary. Dentists generally suggest replacements of toothbrushes every 2 months, hence when needed the application will let the user know that they need to replace the bristle.

Once the decay is detected people might have different states of mind and they might have questions regarding that. Hence a separate section of articles is added where a user can find related information, it is designed to suggest articles based on the need of the user or users can search articles with keywords.

4 Discussions

4.1 Results

As the final output of the research and development, we came up with a toothbrush and a mobile application that will leverage the oral health care lifestyle among people. Without introducing a new product we found ways to subtly integrate technology into the existing behaviour of people that can warn them against potential cavities in their teeth.

The use of multi-frequency AC current to identify hidden cavities has been established and accurate practice among dentists around the world. The Oro White toothbrush has been conceptualised to use similar technology integration in an electric toothbrush and aims to warn the users, not to diagnose any cavity or cavity related problems. The application on the other hand has created an ecosystem among people, dentists and service providers for an organised and systematic oral health care practice.

The user research suggested participants are not willing to use a new product for oral health care, but they preferred a known behaviour enhanced with technology for the same. The participants also disagreed to invest/buy "Oro White Toothbrush" citing the reason of cost.

User testing on the 3D printed prototype for ergonomic evaluation helped us redesign the form of the toothbrush for better comfort with the most common posture identified in user research. The application was designed to be invisible, collecting data in the background for analysis with user consent will generate insights that the user can see at their will or if necessary the app will notify the user over any concern. These interactions were tested during the user testing which helped prioritise the different functionalities and educate the users about Oro White.

4.2 Future Scopes

This combination of product and mobile application leverage the routine of people to have healthy dental health. Over time with the consent of the users, the data collected can be trained using machine learning and the diagnosis accuracy can be increased. The habit building functionality is in its early stage, hence with more research and analysis, the applied method of integrating new features in existing behaviour can be highly beneficial to a healthy lifestyle.

The toothbrush has been considered in a conceptual stage, a 3D printed prototype was used for user testing which can be considered successful in terms of form and design. Including all the mentioned technology can make the Oro White toothbrush expansive. Hence elaborate research has to be performed to ensure a consumer's worth of money on such a toothbrush. Feedbacks from the user testing participants

were affirmative on the practicality of a high tech toothbrush for daily use. Furthermore, the heuristic evaluation of the entire product has been described as a futuristic product and highly beneficial if it can be developed and produced.

4.3 Limitations

Throughout the process of research, many areas were conceptualized based on study references of published sources. The soft electrode is made of materials that may degrade quickly upon repetitive use, hence more stable or structurally strong electrodes are essential for the product. The form of the 'Oro White' toothbrush has not validated the assembly of internal components that are a basic part of an electric toothbrush. Integration of the new sensors and wireless connectivity circuits may require more room or new assembly techniques. These products are viewed as speculative and ahead of time during heuristic evaluation and user research.

In this research and product development, we did not have the opportunity to extend our inclusivity towards specially-abled people. Further research is essential for the inclusivity of all kinds of users.

4.4 Conclusion

Lifestyle innovations can be considered as introducing novel solutions and ideas to the problems that persist today in society and catering to the needs of people's everyday life and their needs. In the process of addressing the problem, we discovered oral health is often neglected and implementation of cutting edge technology is yet limited. By introducing the Oro White toothbrush and mobile application, a tangent of the bigger problem has been called upon to be solved. As a future scope, the toothbrush with the well-researched implementation of technology will be able to keep oral health among people in check.

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Bengalee Adolescents' Auditory and Allied Issues: A Study in Southern Bengal

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Abstract Transportation noise including road and railway traffic noise is recognized as the foremost source of environmental noise exposure. Long-term exposures of transportation noise impose physiological stress in terms of cardiovascular disease and noise annoyance regarded as a health related outcome of well-being itself, leads to anger, disappointment, dissatisfaction, helplessness, anxiety, exhaustion also decrease the quality of life, including psycho-physical functioning, apart from hearing impairment. Concern to the context, here the work is conducted to evaluate the influence of noise exposure on the auditory health profile of total 255 male and 180 female adolescents (16–18 years). The information related to noise annoyance status and Quality of life was recorded. Also 243 male and 219 female adolescents of similar age, residing in a comparatively less noisy and quiet rural area, constituting the control group participated in present work. It has been observed that the study participants both male and female, residing in noisy environment are significantly suffering more from auditory impairment with higher level noise annoyance and significantly poorer quality of life compared to the control group individuals of similar age and sex, which may help to conclude that regular exposure to noise has negative auditory and allied impacts on the adolescents residing in noisy urban environment.

Keywords Environmental noise exposure · Audiometry · Auditory impairment · Annoyance level · Quality of life

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1 Introduction

Environmental noise is considered as one of the most widespread nuisances and a depressing upshot of global rapid unplanned socio-urban development. Science and technology improve social connectivity and since industrial revolution; transportation gained various addition to move faster [1]. Traffic including road and railway is the most prevalent source of community noise which influence people in their residence and place of work [2]. Extensive exposure of different community noises including traffic noise is imposes different negative effects on public well-being, including elevated blood pressure, cardiovascular diseases and psychological well-being [3]. A common human emotional and attitudinal response to noise is described as annoyance. Noise annoyance is universally acclaimed indicator of environmental wellbeing and most important sign of consequent health effects cause by noise exposure [4]. It obstructs human abilities on the way to perform properly and more specifically, quality of life [5]. In Southeast Asia, most of the metropolitan cities are suffering from the burden of elevated decibel and the availability of quiet places is decreasing [6]. Therefore, individuals are continuously bombarded by high level of noise, with unpredictable elevated intensities and prolonged span of exposure, in their residential and workplace environment; children are not exception to it [7]. The constructive improvement of the auditory system is considerably influenced by auditory inputs during the developmental stages of life when the system is most susceptible to alteration by acoustic experience [8]. On the other hand, the increasing cases of road accidents, which represent a significant number of casualties, happened in noisy road intersections for pedestrian misperception of approaching vehicles [9]. In this context, the present work is conducted to evaluate the impact of environmental noise on the auditory health condition and perception related to noise annoyance and quality of life among adolescent residing in urban area.

2 Methodology

To initiate the study, necessary permission from the institutional human ethical committee and the academic institutions situated in and around southern part of West Bengal, was obtained. The study was carried out on 255 urban Bengalee adolescent male and 180 females between the age group of 16–18 years, inhabiting and attending academic institution near busy urban area constituting the exposed group (EG). On the other hand 243 consenting male and 219 female bengalee adolescents of similar age group, inhabiting in a relatively less noisy and calm rural region, considered as control group (CG).Consenting participants with self reported chronic auditory complications were excluded from the study. Information regarding their socioeconomic condition was recorded in predesigned format. Standing strature (cm), using stadiometer with an accuracy of 0.1 cm and body weight (kg), using digital weighing scale with an accuracy of 0.1 kg with participants in light clothing and without shoes

and head in the frankfort horizontal level, were measured and Body mass index (BMI) was assessed. The back ground noise level in different places of the concerned academic institutions and background noise level of audiometric room was checked at regular intervals by using digital sound level meter [10]. Audiometric assessment was conducted [11, 12] with a portable digital audiometer for obtaining the auditory threshold at various frequencies (0.25–8 kHz) [13], for each individual at a time for both left and right ears independently applying the air conduction approach in pure tone [14, 15]. The auditory impairment level was assessed [16] and degree of auditory impairment was calculated as per WHO hearing impairment classification [17–19]. Assessment of the psychological health in terms of individual performance of participants in the study with special reference to quality of life [20], level of annoyance was assessed. The noise annoyance level was assessed using authentic "noise annoyance questionnaires" with tested 5-point scale (based on severity levels like '0' denote to 'Not at all', '1' denote to 'Slight', '2' denote to 'Moderate', '3' denote to 'Very, '4' denote to 'Extreme') prepared, trialled and suggested by experts from The International Commission on the Biological Effects of Noise (ICBEN), [21, 22], as responded, were assessed. Obtained data were tabulated and used for further statistical analysis using SPSS with significance levels were set at $P < 0.05$.

3 Results

The fundamental profile of CG and EG individuals both male and female is presented in Table 1.

There was no significant separation in terms socioeconomic condition among CG and EG participants both male and female.

The physical and physiological profile of the CG and EG participants both male and female is presented in Table 2.

There is no significant variation in terms of age and stature among CG and EG males is observed but the body weight and BMI of CG males is significantly varied ($P < 0.05$) compared to their EG counterparts. There is no significant dissimilarity observed in terms of age, stature, body weight and BMI among CG and EG females.

Table 1 Fundamental profile of study participants

Demographic feature	CG	EG
Habitation	Rural region of Hooghly, W. B	Urban area, Southern W. B
Religion, caste	Hinduism, general	Hinduism, general
Educational institution being attended	Public funded	Public funded

Table 2 Physical and physiological profile of CG and EG participants (a) Male and (b) Female

Male		
Variables	CG (n = 243)	EG (n = 255)
Age (years) [a]	16 ± 0.75	16 ± 0.62
Stature (cm) [a]	163 ± 7.88	162 ± 10.19
Body weight (kg)[*]	50 ± 9.29	52 ± 11.73
BMI[*]	19 ± 3.09	21 ± 3.57
Female		
Variables	CG (n = 221)	EG (n = 180)
Age (years) [a]	16 ± 0.64	16 ± 0.59
Stature (cm) [a]	152 ± 5.17	151 ± 10.32
Body weight (kg) [a]	48 ± 5.99	47 ± 9.26
BMI [a]	20 ± 4.93	20 ± 4.31

[a] ns
[*] $p < 0.05$

In Fig. 1, The average auditory threshold level in dB (A) at various frequencies for both ears of the CG and EG Males is graphically presented.

The bilateral auditory impairment status and the degree of auditory impairment of male study participants according to WHO hearing impairment criterion is presented in Figs. 2 and 3.

In Fig. 4, The average auditory threshold level in dB (A) at different frequencies for both ears of the CG and EG Females is graphically presented.

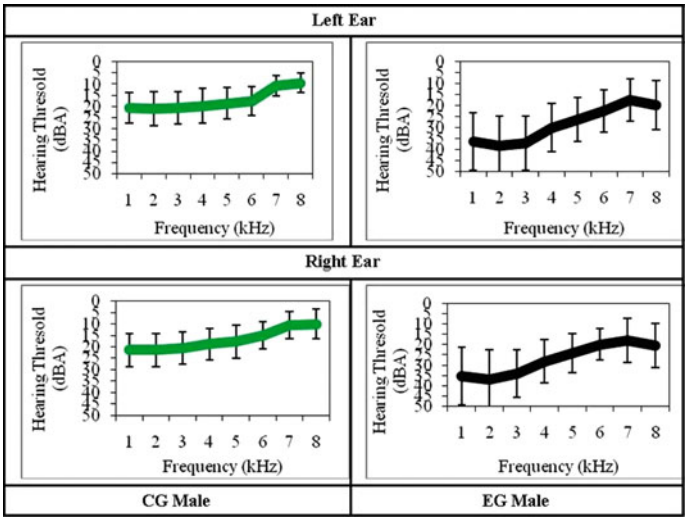

Fig. 1 Average auditory threshold level in dB (A) at various frequencies (0.25–8 kHz) for left and right ears, of the CG and EG Males

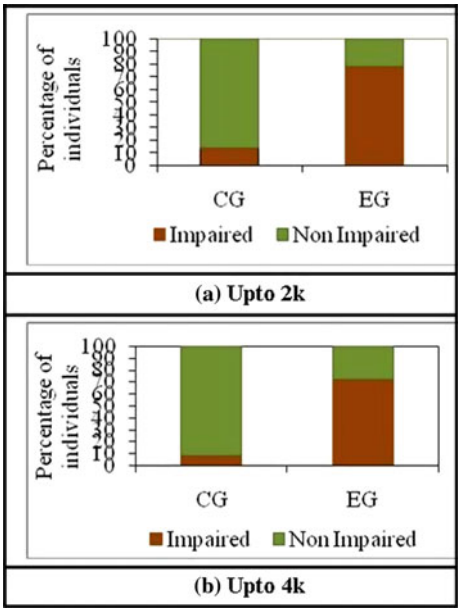

Fig. 2 Comparison in between CG and EG Males with regards to bilateral auditory impairment status according to WHO hearing impairment criterion, upto **a** 2 **kHz** and **b** 4 kHz

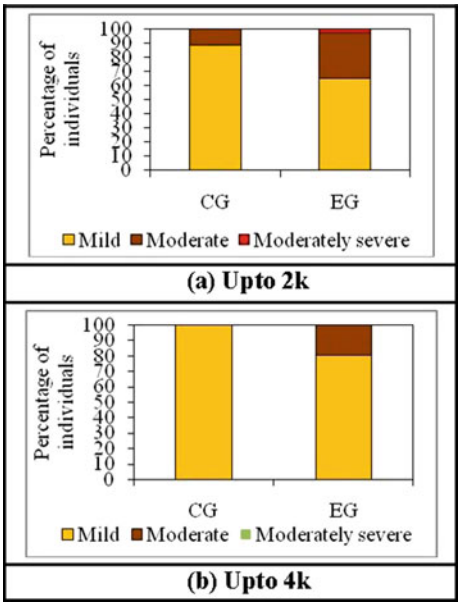

Fig. 3 A Comparison in between CG and EG Males with regards to degree of auditory impairment status according to WHO hearing impairment criterion, upto **a** 2 **kHz** and **b** 4 kHz

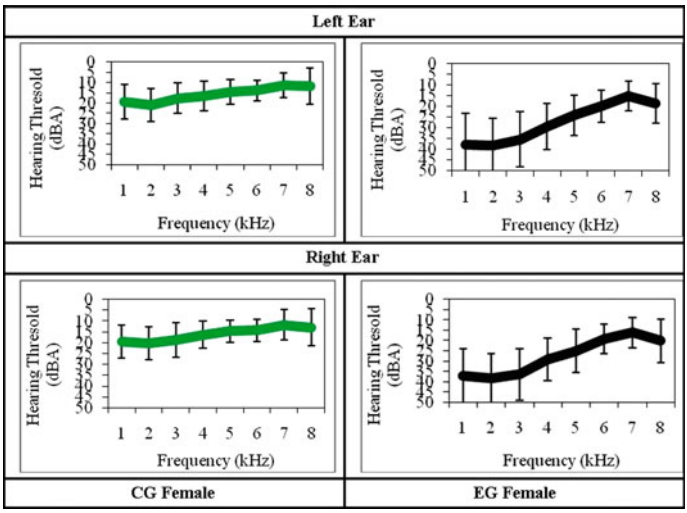

Fig. 4 Average auditory threshold level in dB (A) at different frequencies (0.25–8 kHz) for left and right ears, of the CG and EG females

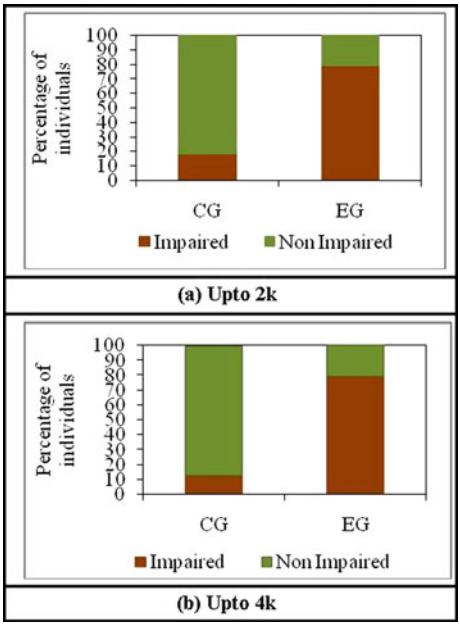

Fig. 5 Comparison in between CG and EG females with regards to bilateral auditory impairment status according to WHO hearing impairment criterion, upto **a** 2 **kHz** and **b** 4 kHz

The bilateral auditory impairment status and the degree of auditory impairment of female study participants according to WHO hearing impairment classification is presented in Figs. 5 and 6.

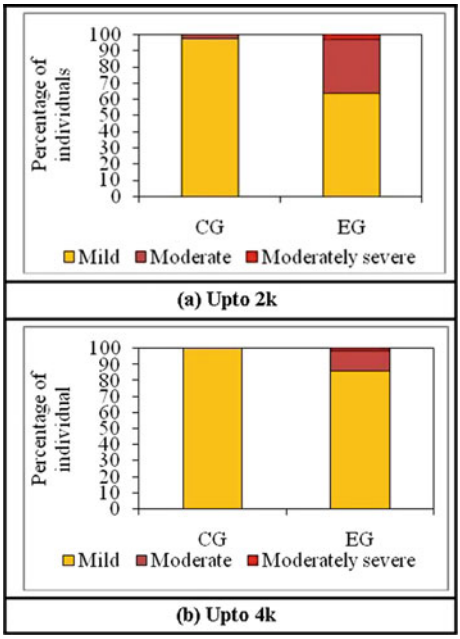

Fig. 6 Comparison in between CG and EG females in respect of degree of auditory impairment status according to WHO hearing impairment criterion, upto **a** 2 **kHz** and **b** 4 kHz

In addition to auditory impairment status, noise annoyance level and the type of annoyance are assessed and the comparison between CG and EG individuals, both male and female, is presented in Fig. 7a, b.

Quality of life (QOL), an important indicator of individual wellbeing, has been considered and the comparisons between CG and EG individuals, both male and female, have been presented in Fig. 8a, b.

4 Discussions

The urban areas, including towns and suburbs, are densely populated areas with almost 400 inhabitants per sq.km and the surroundings are quite developed, in terms of numerous houses, commercial buildings, schools with overcrowded road intersections [23]. Community noise including those from transportation and noise emitted from construction, public work and neighborhood are the main source of noise exposure in urban environment, which is escalating at a very high rate [24]. In this context the present study was conducted on urban adolescent male and female individuals residing and attending educational institution in and around Kolkata. Sound pressure levels (SPL) in the educational institution were estimated periodically and the range has been found to be 74-90dBA which is significantly higher compared to the SPLs of the schools located in rural areas (33–52 dBA). Besides, SPL, L_{eq} is another important parameter for assessing noise level over a specified period. L_{eq} of the schools

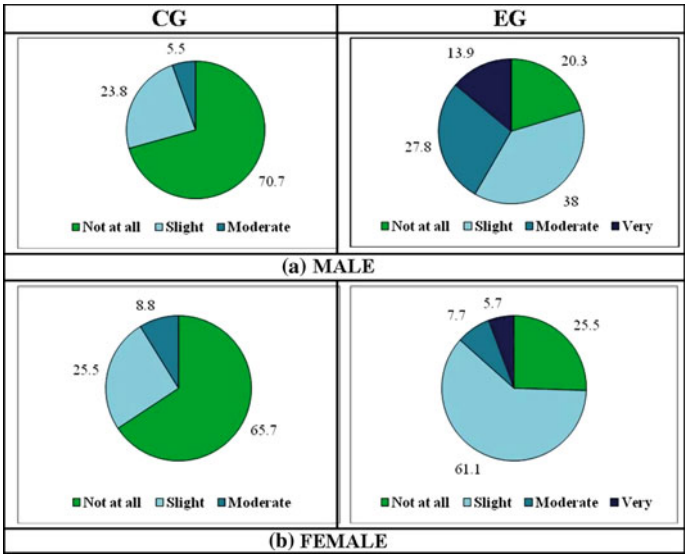

Fig. 7 Comparison in between CG and EG **a** Males and **b** Females in respect of annoyance status

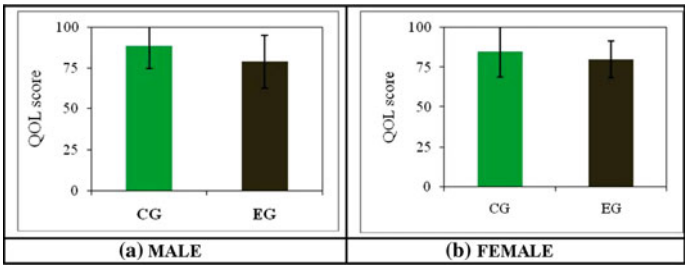

Fig. 8 Comparison in between CG and EG in respect of QOL **a** Male and **b** Female

located in urban area was found to be 75.8 which is far higher that rural area i.e. 41.3 dBA. The result of audiometric assessment indicates that the average threshold shift in both left and right ear was present at speech frequencies among both EG male and female individuals. On the other hand no threshold shift was observed among their respective CG counterparts (Figs. 1 and 4). The present findings are similar to other studies carried out on schools close to the noisy road-intersection and reported that elevated noise level affected the students auditory status adversely [24–26]. The comparable development of result also observed in prior study conducted on school students exposed to railway transportation noise [27, 28] and adolescents involuntarily exposed elevated noise levels [29–32].

The Noise Induced Threshold Shift (NITS) is observed in both ears, among the EG males and females may suggest cumulative auditory damage due to ongoing

exposure. Moreover, it has been observed from the present work that, considering upto 2 kHz level in case of EG males (n = 255) significantly higher, 200, i.e. 78.4% individuals are suffering from bilateral auditory impairment compared to their CG male (n = 243) counterparts 35, i.e.14.5%; similar trend has been found when analysis was performed upto 4 kHz level (EG-185, i.e.72.5% and CG-7.9, i.e. 7.9%) (Fig. 2).In case of EG females (n = 180), it has been observed that (Fig. 5) considering upto 2 kHz level significantly higher percentage of individuals (143, i.e. 79.4%) were suffered from bilateral auditory impairment, compared to their CG female (n = 219) counterparts (40, i.e.18.3%). Similar trend has been found when analysis was performed upto 42 kHz level (EG—79.4% and CG—12.7%).From the results of both male and female individuals in terms of auditory impairment, it may be mentioned that in all frequencies, EG individuals were suffered from bilateral auditory impairment more adversely in comparison to their CG counterparts. The results of the present work are in consonance with the results of other studies carried out on young adolescent population of countries like Korea and India, wherein it was reported that auditory status of adolescent individuals regularly exposed to railway locomotive noise, has been affected significantly[28, 33]. The present findings are also in tune with the study conducted on adolescent population residing in South Africa, wherein it has been reported that, larger number of study individuals had significant hearing loss at speech and higher frequencies, compared to those who live low noisy area [34, 35].

Further going into details, the degree i.e. extent of bilateral auditory impact status was assessed. Among the EG male individuals, among 200 impaired individuals, 65% i.e. 130 individuals suffer from 'mild' hearing impairment, about 32% i.e.64 from 'moderate' and even 3% i.e. only 6 individuals were suffered from 'moderately severe' hearing impairment considering upto 2 kHz; while in case of CG, among 35 impaired individuals, it has been found that 88.5% i.e. 31 individuals suffered from 'mild' type of hearing impairment and 9.6% i.e. only 2 individuals suffered from 'moderate' type of hearing impairment. When the analysis has been carried out, considering upto 4 kHz level, it is found that, among 185 EG male impaired individuals, 80.5% and 19.5% are having 'mild', 'moderate' degree of auditory impairment respectively (Fig. 3). Comparatively, among the rural CG counterparts all 19 impaired individuals were only having 'mild' type of auditory impairment and none has been found to have more serious nature of impairment. In case of EG females, among 143 impaired individuals, 63.6% suffered from 'mild' auditory impairment, about 33.5% from 'moderate' type and 2.9% even suffered from auditory impairment of 'moderately severe' type considering upto 2 kHz; in case of CG, among 40 impaired individuals, it was observed that there is 97.5% i.e. 39 individuals suffered from 'mild' type of auditory impairment and 2.5% i.e. only 1 individual suffered from 'moderate' type of auditory impairment. When the analysis has been carried out considering upto 4 kHz level, it has been found that, among 143 impaired individuals, 86%,12.5% and 1.5% EG females suffered from 'mild', 'moderate' and 'moderately severe' degree of auditory impairment respectively, compared to their rural CG counterparts where all 28 impaired individuals are only having 'mild' type of auditory impairment. The result of the present work are in concurrence with

previous study carried out on adolescents individuals exposed to social noise, suffered from significant bilateral 'mild' to 'moderately severe' degree of auditory impairment compared to group of normal hearing group of adolescents [36] and similarly the present result are in consonance with earlier study conducted on school children exposed to elevated environmental noise level including aviation and railway transportation noise [37–39].

Noise Annoyance is a feeling of discomfort, related to adverse influencing on individual performance level and educational achievements. From the consequence of result of the present study (Fig. 7) it is observed that, significantly higher percentage of EG individuals, both male and female, responded as they were having high noise annoyance level. In case of EG males, 20.3%, 38%, 27.5% and 13.9% were having noise annoyance categorized as not at all, 'slight', 'moderate' and 'very' respectively; whereas in case of rural CG males, 70.7% responded as they do 'not at all' having any noise annoyance and 23.8% and 5.5% responded as they are having 'slight' and moderate level of noise annoyance respectively. Similarly, in case of EG females, 25.5%, 61.1%, 7.7% and 5.7% responded noise annoyance level as 'not at all', 'slight', 'moderate' and 'very'; on the contrary, in case of CG females, 65.7% individuals responded as they do 'not at all' having any noise annoyance and 25.5% and 8.8% responded as they were having 'slight' and 'moderate' level of noise annoyance respectively. The results of the present work are in consonance with the results of earlier study carried out on population residing near railway tracks wherein it has been observed that the residents were found significantly annoyed by noise of passing trains[28, 40] and similar trend of annoyance level has been observed among adolescents residing near busy airport [39, 41], In addition to noise annoyance, quality of life in terms of psycho social wellbeing, memorization and educational performance of the participants were also assessed, as these may be influence by high i.e. unfavorable noise level. In this present work it has been observed that both male and female CG individuals performed with significantly ($P < 0.05$) improved QOL score in comparison to their EG participants. Simultaneously, the results also indicated that noise might also acts as an environmental stressor that affects the quality of life, psychological wellbeing and cognitive ability of the individuals residing and attending schools in noisy urban area. The findings are in consonance with prior work conducted on young population observed with higher scores across all dimensions of the Quality of Life for individuals residing in less noisy areas, compared to those living in "noisy" urban regions [25, 28, 42, 43]. Hence, the present work denotes that in urban environment, regular exposure of community noise, including transportation noise and noise from neighborhood, has unfavorable influence on auditory threshold level of bengalee adolescent at speech frequency and also at 4 kHz which might have apathetic influence on their individual performance.

5 Conclusions

On the basis of the study conducted, it may be concluded that bengalee adolescents inhibiting and attending academic institution in noisy urban area, are having significantly adverse auditory impairment and are having significantly more annoyance, in comparison to the individuals residing in less noisy and quiet rural area. The quality of life status of the EG individuals exposed in noisy environment is found to be poor in comparison to CG individuals.

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Fourth Ventricle Compression (CV_4) as a Method for Stress Management

Praghosh Chhetri and Tirthankar Ghosh

Abstract Apart from stressful interpersonal and societal life situations, poorly designed learning environment and lack of knowledge of ergonomics increase the vulnerability of students to psychosomatic illnesses. Heart rate variability (HRV) has been used to assess emotional regulation capacity as a marker of stress and resilience. HRV is a window to the autonomic nervous regulation and refers to the physiological variation in the interval between consecutive heart beats. Fourth ventricular compression (CV_4) is a commonly practiced cranial osteopathic maneuver which has been found to bring about important physiological effects. This study assesses the CV_4 technique for its immediate effects on HRV parameters and thereby, its potential usefulness in stress management. In this study 25 male osteopathy students of Sri Sri University in the age group of 18–30 were voluntarily recruited. HRV parameters before and after the maneuver were recorded using Polar V800 Heart rate monitor and appropriate comparison was done using SPSS software. After the intervention, significant increases in all the time domain parameters viz. SDNN, RMSSD, NN50, pNN50 as well as logarithmic power of high frequency were noticed. This points towards a substantial shift brought by CV_4 maneuver in the overall autonomic nervous balance towards parasympathetic mode. This study shows that CV_4 brings about an acute parasympathetically dominated relaxation response in young adults and thus can potentially help in short-term stress management.

Keywords Heart rate variability · Compression of fourth ventricle · Cranial osteopathy · CV_4 · Polar V800

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1 Introduction

1.1 Heart Rate Variability: A Window to Autonomic Nervous Regulation

As per Dorland's Medical Dictionary, Autonomic nervous system (ANS) regulates the activity of cardiac muscle, smooth muscle, and glandular epithelium via two visceral efferent peripheral components, the sympathetic and the parasympathetic nervous systems [1]. Acting unconsciously, the ANS influences a wide range of physiological processes to maintain homeostasis and also plays a role in the body's response to an emotional experience [2].

Prolonged imbalance in the autonomic nervous system is linked with a wide range of illnesses [3]. Genetic as well environmental factors play role in the origin and maintenance of complex diseases. Ever changing environmental, societal, and political scenario puts an individual into the risk of an array of psychosomatic disorders. In majority of the cases, overactivation of the sympathetic nervous system and Hypothalo-pituitary-adrenal (HPA) axis is incriminated [4]. Moreover, due to lack of proper knowledge of ergonomics and an optimum design of the learning environment, students particularly in medical, osteopathic, dental and physiotherapy disciplines are very prone to encounter musculoskeletal and varied psychosomatic illnesses [5].

Physical, cognitive as well as emotional activities can influence heart rate in healthy humans [6]. Heart rate variability (HRV) can show the balance between the two branches of the ANS, the sympathovagal balance [7]. HRV reflects physiological variation of spontaneous heart rate assessed by measuring variations in successive RR intervals of an electrocardiogram (ECG) [8].

In clinical settings, HRV is widely used to assess progress and prognosis of diabetic neuropathy, ischemic heart diseases and other cardiovascular conditions [9]. In sports and fitness settings, HRV has been found to give invaluable information on aerobic fitness level, overtraining, recovery etc. [10]. HRV has also been used to assess an individual's emotional regulation capacity as a marker of stress and resilience [11]. Higher resting HRV has been linked to optimum functions of the prefrontal cortex in executive functions and emotional processing [12]. HRV is also gaining popularity in the field of mind–body medicine to analyze the effect of yoga and meditation on sympathovagal balance [13].

1.2 Introduction to Osteopathy

Osteopathy was founded in the late nineteenth century by Andrew Taylor Still, an American physician and surgeon. Osteopathy includes methods of manual diagnosis and treatment based on the basic tenets of A.T. Still: the body is a dynamic functional unit, structures and functions and related, and the body has an intrinsic ability of self-healing. Using a variety of hands-on manipulative techniques, osteopaths focus on

restoring the physiology altered by an impaired function of the somatic system and related components [14].

1.3 Fourth Ventricle Compression: A Cranial Osteopathic Maneuver

First developed by W.G. Sutherland, a student of A.T. Still, Compression of fourth ventricle (CV_4) is a cranial osteopathic technique widely used by practitioners of manipulative therapy [15]. Out of many physiological effects of CV_4, an important one is the reduction of sympathetic tone with alleviation of stress symptoms [16].

Several research works have shown the effectiveness of this technique of cranial osteopathy. Cutler et al. in 2005 found that CV_4 technique brought about a significant reduction in sleep latency in the study group [17]. Miana et al. in 2013 found that CV_4 technique brought about a significant increase in alpha-absolute power of EEG post intervention compared to the same before the technique was given [18]. Hanten et al. in 1999 conducted a study in sixty adults with tension type headache, where, significant pain relief was seen in the group treated with CV_4 compared to the group with no treatment [19]. In the experimental controlled study done by Curi et al. in 2017, significant blood pressure reduction was seen in the hypertensive group after the CV_4 technique. Increased parasympathetic and decreased sympathetic activity was also seen in both the groups (hypertensives and normotensives) post intervention as shown by reduction in LF/HF ratio in HRV analysis [20]. However, research supporting the benefits of CV_4 on autonomic nervous functions and HRV and hence stress is scanty. The aim of this study was to assess the immediate effects of CV_4 on heart rate variability and thereby assess the autonomic modulations brought about by the technique on young male subjects.

2 Materials and Methods

2.1 Procedure

This study was an interventional before-after study conducted in the Department of Osteopathy, Faculty of Health and Wellness, Sri Sri University, Cuttack, Odisha, India. Data collection was done over a period of about 1 month (10th February to 12th March, 2021) after obtaining ethical approval from the institutional review committee. A total of 25 male students of Sri Sri University in the age group of 18–30 years were voluntarily recruited using convenient sampling method. Participants with recent head trauma; those with any psychiatric, neurological or other systemic disorders that constitute contraindications of cranial osteopathic techniques [14]; and those under medications that can potentially influence the ANS were excluded from

the study. Only the participants not having COVID-19 diagnosis or related symptoms were included in the study.

The study sessions were conducted inside an air-conditioned osteopathy clinic of the department of Osteopathy, Sri Sri University. Informed consent of the subject was taken followed by a detailed case history. The participants were instructed to refrain from stimulants like tea, coffee and alcohol and not to indulge in strenuous physical activity at least 12 h prior to the intervention and HRV analysis. Five-minute baseline HRV assessment (Pre-test) was done after 15 min of quiet supine rest with eyes closed and normal breathing. The baseline measurement was followed by the CV_4 technique. The last five minutes of the intervention was analyzed for post-intervention analysis of HRV (Post-test).

2.2 Administration of CV4 Maneuver

Figure 1 shows administration of CV_4 which involves gentle manipulation of the cranium by holding the squamous part of the occipital bone while the client is lying supine. The thenar eminences are placed posteromedial to occipitomastoid sutures on the squamous part of the occipital bone. Cranial rhythmic extension of the occiput is encouraged and flexion resisted by maintaining the occiput in extension with medially directed force until a release is felt and/or a still point is reached [21].

2.3 HRV Data Acquisition and Analysis

In this study, HRV was measured and recorded using Polar V800 heart rate monitor and polar H7 heart rate sensor attached to a chest strap worn tightly but comfortably just below the chest muscles at the level of the xiphoid process. The chest strap electrode was moistened with conducting gel before applying to the chest [22]. The Polar device has built-in function that stores raw RR data in the electronic form. The raw RR data were transferred to a computer and the HRV assessment done using Kubios HRV Software [23]. Giles et al. compared the validity of Polar V800 HRM to standard ECG in twenty participants and found strong intra-class correlation, narrow limits of agreement and smaller effect size, thus pointing to a significantly comparable detection of RR intervals at rest [22].

The time domain HRV indices used in the study were SDNN (Standard Deviation of intervals between normal *R* waves resulting from SA node depolarization i.e., NN intervals), RMSSD (Square root of the mean of the squares of successive differences), NN50 (Pair of successive NN intervals differing by more than 50 ms) and pNN50 (Proportion of NN50 divided by the total number of NN intervals). The frequency domain indices used were log converted high frequency power (HFlog), low frequency power (LFlog) and total absolute power (TPlog), normalized units of

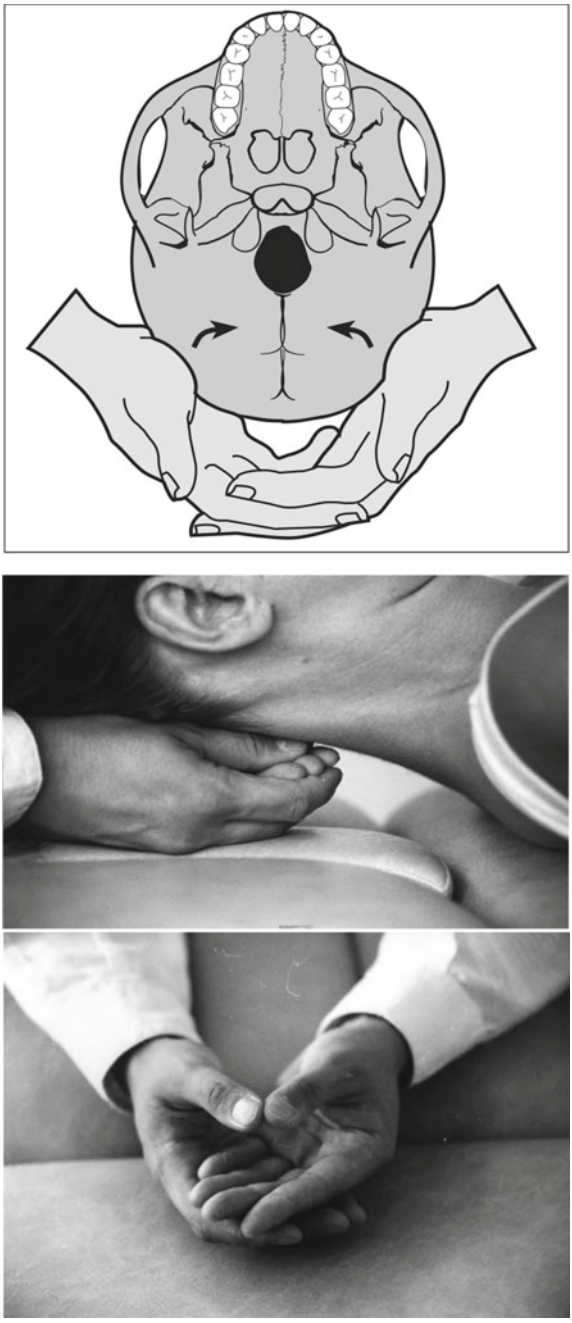

Fig. 1 Administration of CV_4 osteopathic technique [16]

low frequency (LFnu) and high frequency power (HFnu), and ratio of low frequency to high frequency (LF: HF).

3 Results

A total of 25 healthy participants within the age group of 18–30 were recruited for the study. All of the participants were bachelors and masters level osteopathy students of Sri Sri University, Cuttack, Odisha. Table 1 shows the anthropometric parameters of the participants. The mean age, height, weight and BMI were 21.6 ± 2.36 years, 172.28 ± 9.19 cm, 72 ± 10.12 kg and 24.31 ± 3.32 kg/m^2 respectively.

Statistical analyses were done using IBM SPSS software. Before-after comparison of the data was done by paired sample t-test. The level of significance was set at p-value less than 0.05.

Table 2 shows time domain parameters before and after CV_4. Paired sample t-test: SDNN, RMSSD, NN50 and pNN50 showed significant increase ($p < 0.001$) after CV_4.

Table 3 shows frequency domain parameters before and after CV_4. Paired sample t-test: HFlog, LFlog and TPlog showed significant increases ($p < 0.001$) after CV_4. There was increase in HFnu and decrease both in LFnu and LF: HF, but the differences weren't statistically significant ($p > 0.05$).

Table 1 Anthropometric parameters of the participants.

Anthropometric parameters	*N = 25*
Age (years)	21.6 ± 2.36
Height (cm)	172.28 ± 9.19
Weight (kg)	72 ± 10.12
BMI (kg/m^2)	24.31 ± 3.32

Table 2 Time domain HRV parameters before and after CV4

Parameters	Before (Mean ± SD)	After (Mean ± SD)	*p*-value
SDNN	46.22 ± 16.96	64.37 ± 23.40	<0.001
RMSSD	51.18 ± 23.59	70.07 ± 31.83	<0.001
NN50	87.72 ± 56.70	123.76 ± 56.57	<0.001
pNN50	27.02 ± 19.37	38.00 ± 19.56	<0.001

Table 3 Frequency domain HRV parameters before and after CV_4

Parameters	Before (Mean ± SD)	After (Mean ± SD)	*p*-value
HFlog	6.63 ± 0.98	7.39 ± 0.84	<0.001
LFlog	6.66 ± 0.88	7.31 ± 0.83	<0.001
TPlog	7.39 ± 0.89	8.12 ± 0.77	<0.001
HFnu	49.28 ± 9.27	51.68 ± 13.23	NS
LFnu	50.66 ± 9.29	48.26 ± 13.27	NS
LF: HF	1.11 ± 0.44	1.08 ± 0.62	NS

4 Discussion

The purpose of this study was to analyze the immediate changes in the HRV indices brought about by CV_4 technique and thereby assess the possible usefulness in stress management. The data showed that CV_4 brought about significant changes in all the measured time domain HRV indices and most of the frequency domain indices. Compared to the baseline pre-intervention data, significant elevations were seen in all the measured time-domain indices viz. SDNN, RMSSD, NN50 and pNN50. In frequency domain parameters, there were significant elevations in HF (log), LF (log) and TP (log). There was increase in HF (nu) and decrease in both LF (nu) and LF:HF ratio, however, these differences were not statistically significant.

According to Shaffer and Ginsberg, the time domain indices that have been used in this study viz. SDNN, RMSSD, NN50 and pNN50 are strongly correlated with high frequency power and therefore parasympathetic autonomic nervous activity [24]. Low frequency HRV power is under both sympathetic and vagal influences and thus cannot be considered a pure index of sympathetic nervous drive. Hence the frequency domain indices which take LF power for their calculation viz. normalized units, total power and LF:HF ratio have not been considered as reliable indices of sympathovagal balance, at least in short term HRV analyses [25, 26].

In this study, significant post-intervention elevations in SDNN, RMSSD, NN50 and pNN50 are correlated with a significant post-intervention elevation in HF power which indicates a shift of autonomic balance to parasympathetic or vagal mode (Fig. 2a–e).

Prolonged exposure to stressful life situations in interpersonal as well as societal levels have negative repercussions on the physical and psychological health of a person via chronic activation of sympathetic nervous system and hypothalamo-pituitary-adrenal (HPA) axis [3]. Students are vulnerable to day-to-day stresses owing to changing environmental and sociopolitical scenario, increased academic demands and competition and a pressure to maintain balanced interpersonal relationships. Particularly, medical, dental, physiotherapy and osteopathic students are even more subject to musculoskeletal and psychosomatic illnesses related to poor posture due to a lack of knowledge of ergonomics and imperfectly designed learning environment

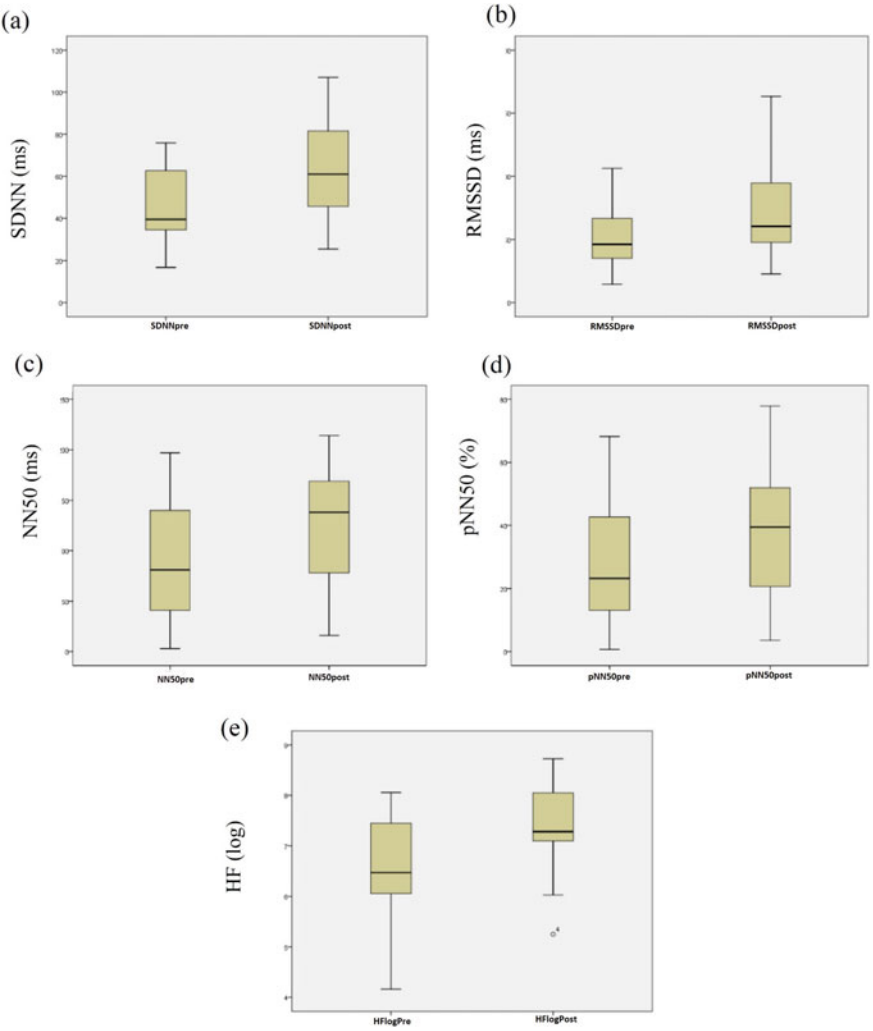

Fig. 2 **a** Post intervention SDNN (64.37 ± 23.40) was significantly higher ($p < 0.001$) than the base line (46.22 ± 16.96). **b** Post intervention RMSSD (70.07 ± 31.83) is significantly higher ($p < 0.001$) than baseline (51.18 ± 23.59). **c** Post intervention NN50 (123.76 ± 56.57) is significantly higher ($p < 0.001$) compared to the baseline (87.72 ± 56.70). **d** Post intervention pNN50 (38.00 ± 19.56) is significantly higher ($p < 0.001$) compared to the baseline (27.02 ± 19.37). **e** Post-intervention HFlog (7.39 ± 0.84) is significantly higher ($p < 0.001$) than the baseline (6.63 ± 0.98)

[5, 27]. HRV measures have been positively associated with resilience to stress, and negatively correlated to stress and negative behavioral states [28].

According to Torsten Liem, CV_4 works via direct activation of nuclei of cranial nerves in the ventricular system and also via its effect on the periaqueductal gray matter [16]. The findings of this study point toward a relationship of CV_4 with

parasympathetic activation as shown by significantly improved time domain HRV indices and high frequency power. The results, thus, are in accordance to the hypothesis which pointed to a favorable parasympathetic modulating effect of CV_4.

Due to paucity of research on the effect of CV_4 in ANS including changes in HRV, comparative analysis of the current study with past studies could not be up to the mark. However, the results of the study were in keeping with the works done by Curi et al. [20] and Cardoso-de-Mello-e-Mello-Ribeiro et al. [29] that showed a positive effect of CV_4 in producing parasympathetically driven relaxation response.

This study assesses the immediate effects of CV_4 technique in HRV of only young adults. A longer duration study can be done to assess long-term effect of the technique. Further, a larger sized randomized controlled study incorporating subjects of different age groups of both genders can be expected to produce results representative of the general population.

5 Conclusion

According to Herbert Benson, relaxation response of the parasympathetic nervous system counteracts the physiological effects of stress and fight-or-flight response, and with regular practice may be of preventive and therapeutic value in conditions due to increased sympathetic activity [30]. The findings of this study show that CV_4 can bring about immediate increase in parasympathetic mode of ANS as shown by significantly improved HRV indices post-intervention. CV_4 can prove to be a fairly effective outpatient manual treatment to students going through sympathetically driven life situations like performance anxiety, interpersonal discord, career uncertainties etc., further compounded by ergonomically poor posture during practice and the design of the learning environment which is not up to the mark.

Conflicts of Interest The author declares no conflicts of interest.

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Enabling Sign Language Recognition Feature in Video Conferencing

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Abstract Pandemic situation has a major impact upon students in the mode of education. Students get back their quality of education through online mode supported by various platforms like Google Meet, Zoom etc. Still there exists a social group of students with oral and aural difficulties who suffer to get quality education online which is really pathetic to hear. Our paper aims to develop a special educational platform for the differently-abled students in order to make their conversation easier with a normal teacher through video conference (converting sign language into caption) as well as converting the voice of normal teacher into captions for easy understanding of differently-abled students (converting voice to caption).

Keywords Indian sign language gesture · Voice recognition · Peer-to-peer connections · Transfer learning with convolutional neural network · Tensorflow with object detection api

1 Introduction

In recent times, understanding human emotions is becoming increasingly difficult, day-by-day. One true development is that humans are learning to empathize. It's when humans truly empathize, they get to understand others feelings and when they begin to understand others' emotions, they communicate better. This is a big matter of challenge when it comes to differently abled people. Differently abled people speak in Sign Language and it takes us to learn Sign Language in order to communicate with them. This communication amidst differently enabled people and others can be highly improved by the form of an application where the users can speak in sign language and get their translation right in the form of captions, more like subtitles for a movie or a documentary. Our application aims at translating sign language

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characters on every end (i.e.) both the caller and the callee side of the application. The application uses Object recognition and deep Learning algorithms to identify the gestures made by the user in the video stream. It is then further identified by making use of classifiers and the character is displayed in the form of subtitles or captions below on the other end. When the caller makes a character, the translation is received on the callee side.

Sign language is a power tool for differently abled people to communicate. Sign language recognition improves deaf and dumb people to communicate thereby removes accessible barriers and improving their social inclusion [1]. Sign language must be improvised using technology such that it gets adapted to all circumstances and withstand all situations of the world.

2 Motivation

Communication is one of the fundamental and important aspects of our daily life in society. Here sign language is an important communication tool for differently abled people. Normal people feel difficulty in understanding their languages because they hardly know sign language. Hence it becomes more complicated when a person who has the inability to speak and hear wants to convey some messages to them [16]. However, with the development of the internet, there are more and more sign language learning platform videos available for the differently abled people, but it is not convenient to them. The enabling sign language recognition feature in video conferencing aims at reducing the complexity in sign languages and to convey the message easily through the video conferencing with hand gestures. This contains special features in video call between deaf and dumb people to normal people such that the sign language used by deaf and dumb people will get translated into captions to normal people and the voice of the normal people gets translated into captions to deaf and dumb people and in this way communication is made possible at both the ends. Even Google is trying to improve Sign language recognition and merge it through video conferencing [2].

3 Related Works

Certain papers published aim to work regarding the identification of sign language gestures and converting to text. Here they have used Back propagation neural networks on American Sign Language dataset [3]. This dataset is limited in such way that we have only alphabets and number gestures which is even very easy to understand by normal people so the use of model isn't great focused on welfare as well Indian Sign language gesture and American Sign language gesture varies. Some other journals aim to extract the action gestures in running videos, channels, movies and aims to translate in text or captions below. They have implemented the

classification using Support Vector Method algorithm [4]. In case if the video isn't clear the gestures be identified. So coherence can't be achieved.

Some papers encourage to develop computer vision sign language system for better use in animated series for better quality education for disable [5]. Other papers has various methods to recognise the static gestures through image processing [6], object recognition [20], SVM [4] and Dynamic gestures using HSV detection [7, 12]. These papers aims to do only feature extraction for identification within the given data sets. They have no idea to enlarge the dataset for wide use.

4 Challenges

The dataset which we have chosen as the best has a smaller number of trained images for the word as well as it contains very few words with trained hand gestures [11]. It could be improved by adding more words with appropriate hand gestures by some experienced faculty. At the same time the hand gesture (Sign language) way of communication differs from country to country. We have different datasets for Indian and American differently abled students. So, the mode of communication trained to the video call might vary for different countries. So we decided to create a dataset by ourselves.

5 Building Deep Learning Model

5.1 Preparing Dataset

Before building a Deep learning model we have to prepare training and test datasets for prediction or classification [15]. So, we have opted to prepare the dataset by collecting the images through python and labelling the poses (gestures) for object detection. A dataset should be prepared at a large scale such that it consists of all words that the differently abled people use in their day-to-day life. It could be achieved by a Sign language expert's guidance. Due to time constraint our dataset is prepared with certain words that we are aware of [14]. Those Sign Language poses are captured by the webcam and those frames are saved for labelling. The biggest advantage in deep learning is that we don't need to feature extract manually.

5.2 Collecting and Labelling Images for Object Detection

Collection of images is done through python opencv and labelling them through image packages. Frames captured are going to train up into a dataset and set to label

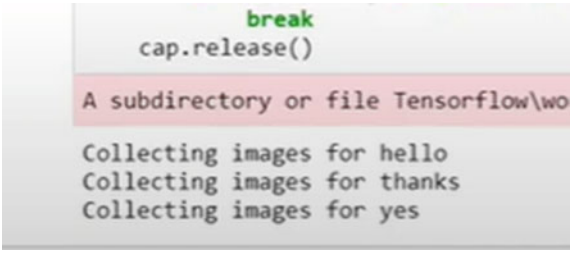

Fig. 1 Collecting images for pre-training

it. With the help of labeling tool of python called Label Img we identify the hand gesture pose and make a square around it which will make detection and identification earlier. Real time Sign Languages are detected through webcam by the trained fixed hand gestures in frames. The dataset is split into training dataset and testing dataset in 4:1 ratio. To map each label a unique id is created for each labelled hand gestures. The training and test datasets are tf records which is going to play a major part in prediction (Fig. 1).

5.3 Training Tensorflow for Sign Language

Here, we have to configure the existing pretrained model through pipeline configuration. Batch size is increased for configuration and data is processed in epoch which is equal to the number of iterations and the datasets are passed through the program and updated for fine tuning. In case of increase in loss metrics during training the data through transfer learning the number of steps should be increased. Increase in the number of steps reduces the loss metrics. Transfer learning with CNN is one of deep learning classifiers makes use of previously acquired knowledge and skills in new learning or problem-solving situations.

5.4 Test Detect Sign Language in Realtime

Running images through a webcam in real time is given as an input as model gets detected as shown in Fig. 2.

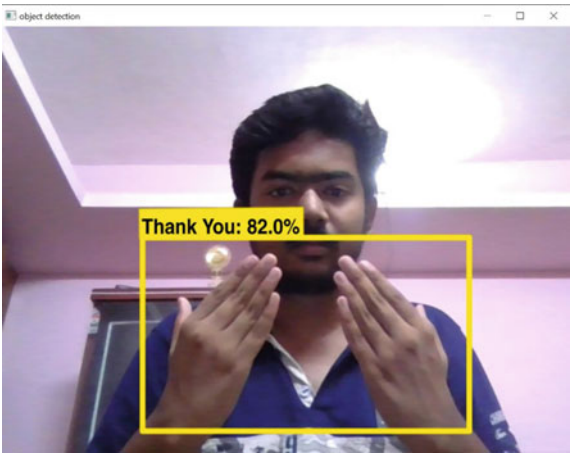

Fig. 2 Result of training dataset

6 Algorithms and Tools Used

6.1 LabelImg

LabelImg is a tool that is written in python and is used for annotating files. The results of the annotations are saved in .xml format and it also supports yolo format files.

6.2 OpenCV

Opencv-python is a python library that binds and designs to solve computer vision problems. It makes NumPy, which is the most higly rated library of python for numeric options with matlab style syntax.

6.3 Keras

Keras is a python library that helps in supporting models of neural networks either fully connected, convolution or current etc.

6.4 Tensorflow

Tensorflow is also a python library for fast numerical computation. It is created and released by Google.

6.5 Transfer Learning with CNN

Transfer learning transfers as much knowledge as possible from the previous task. The model was trained on to the new task at hand. Transfer learning with CNN using VGG 16 model is suitable for building sign language deep learning model. The last layer of transfer learning CNN model is changed for our convenience and logic to train the dataset.

7 Methodology

First of all, a 3-tier system peer to peer connection video conferencing is built using python libraries. The video Conferencing contains 2 modes [8]. Differently abled mode and [9] normal mode. In Differently abled mode, between the peer-to-peer connection the frames per second are collected and sent to the deep learning models built through api call for prediction purpose before it reaches the receiver side. Once the frames get predicted, the results (text) are sent to the receiver's end as captions. In the normal mode, the voice of people gets translated into text which could be done by google cloud speech-to-text api call between peer-to-peer connection. The differently abled people can get their points through captions below their screen. So, this would make the social group of people to communicate easily with the society in the virtual world.

7.1 Building Video Conferencing

Here to manage with the deep learning models api runs simultaneously along the webcam we have opted to using threads and multiprocessing python libraries. The threads are programmed to read the webcam streams i.e., the frames. The video feed scripts are fixed to initialize threads, cam video capture [10], set data and display the images. Video socket script manages the transfer of fixed size from string over common sockets. Here we have to establish the peer-to-peer connection for group video calling conferences.

7.2 Hybrid Peer-to-Peer Connection with Object Detection API

Peer to peer connection is one of the most promising technologies where it will renovate the architecture of distributed network systems. Here each peer (node) can act as both server and client. In a peer-to-peer network each peer can make requests to other peers and could also respond to the request received from other peers. The performance of such networks could be increased if the number of peers joining increases. These peers can collaborate and share a good bandwidth with each other to complete the task given. If a differently abled mode is chosen, then the frames of each sign language frame are collected per second and sent to the deep learning models built for prediction through api call.

Once the text prediction is ready it is set back to peer connection to deliver it to the receiver. In case of the second mode i.e., the normal mode is chosen, then the voice gets recognized and converted into text through google cloud speech-to-text api in between its peer-to-peer connection. As soon as it gets converted into text then the text output is made available to the peer connection to deliver it to the receiver side.

The Sign language frames which are to be collected from the differently abled mode chooser's side are to be stored in cloud for prediction analysis of deep learning models that we have built. It cannot be done or made run in a local host because it may cause damage to the machine due to machine learning complex performance. If it's hosted in the cloud, this could be handled safely.

7.3 Tensorflow Object Detection Api

Image obtained as an Input is now passed to the deep learning model built and classified words from tf records obtained through prediction. Those words are transferred as a stream of bytes in the peer connection to be delivered at the receiver side as a caption.

7.4 Predicted Output and Results

The sign Language recognized frames are compared with training data sets and predicted and result obtained will be sent to peer-to-peer connection to be delivered to the receiver end as captions. Figure 3 represents the graph, depicting the accuracy of several algorithms applied on the dataset. We can see that the most mixed-up alphabets when coming to recognition are letters M and S. Improvising on the accuracy would be much more effective.

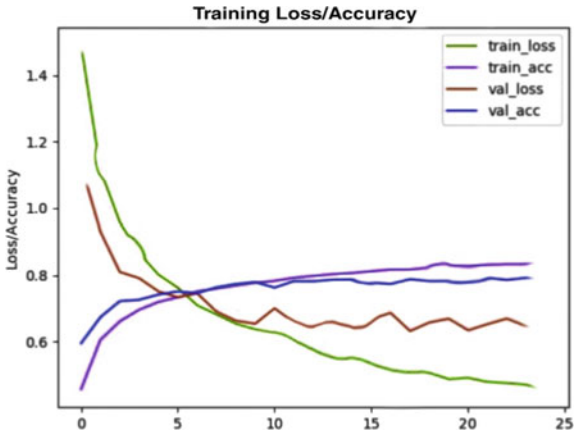

Fig. 3 Training loss/accuracy graph

Fig. 4 Pictorial representation of sign language video conferencing

7.5 Mode 2 (Normal Mode Functions)

Here we are provided with Google cloud speech-to-text api for voice to caption conversion which is called in between the peer-to-peer connection of Video conferencing. Once the voice gets converted to text it is returned to peer connection to be delivered to the receiver's side as captions (Fig. 4).

8 Conclusion

In this paper we have implemented a sign language recognition feature in video conferencing, where the users can communicate in sign language and get their translation in the form of captions. Our project aims to develop a special platform for the differently-abled people in order to make their conversation easier with normal people through video conference (converting sign language into caption), further converting the voice of normal people into captions for easy understanding of differently-abled people and thus both the people communicate. This application uses Image recognition and Machine Learning algorithms to identify the character made by the user in the video stream. It is then further identified by making use of classifiers and the character is displayed in the form of subtitles or captions below on the other end**.**

9 Future Work

The model used in this project can be trained using other algorithms to improve accuracy of identification of symbols. Further improvements can be done to the application by adding further features like messaging and making the application as a form of social media. Voice recognition can also be implemented to improve the usability of the application. This project has a great scope in bridging the communication gap amongst the differently-abled people and others and is worthy of improvising [17].

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Effect of a Six Week App Based Ankle Proprioception Training Program on Balance in Fencers

Srinivasa Rao Pachava and Simran S. Shakeel

Abstract To achieve peak performance while avoiding lower-limb injuries, superior balance is a prerequisite, in most sports including fencing. Because the ankle–foot complex is the only region of the body that is in contact with the ground during most sports related movements, ankle proprioception is perhaps one of the most vital components in maintaining balance in sports activities. Fencing is an open-skilled combat sport based on complex footwork which demands strength, flexibility, and stability of the lower limbs. App-based rehabilitation programs leverage on video games' intrinsic motivational potential by allowing players to operate a game through the use of a wobble board while performing prescribed exercises. Therefore, the goal of this study was to evaluate how a six-week balance and proprioception training program using a smartphone app impacted fencers. Ten university level fencers of Guru Nanak Dev University between the ages 18–23 years volunteered to participate in the study. A smartphone app (Classic Labyrinth 3D Maze—The Wooden Puzzle Game, Developer—Cabbie Games, Version: 7.7) and a wobble board were used to train balance and proprioception for six weeks. Kinematic Measurement System (KMS) and lower quarter Y balance test were used to measure balance before and after the intervention. A significant increase in the absolute and relative reaches in all three directions of the Y balance test and a reduction in the contact times in KMS was observed following the intervention. This training program is effective for improving balance in fencers.

Keywords Balance · Fencing · Interactive Rehabilitation · Smart Phone Application · Proprioception

1 Introduction

Exceptional balance is required for peak performance and lower extremity injury in most sports [1, 2]. Visual, vestibular, and proprioceptive information are all integrated

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by the central nervous system (CNS) to produce motor signals that control balance and synchronise muscle activation patterns [3, 4]. The ability to determine body location by integrating sensory data from numerous mechanoreceptors and spatial movement [5, 6] is called proprioception, it plays a vital role in controlling balance [7–9] . Because the ankle–foot complex is the only region of the body that is in contact with the ground during most sports related movements, ankle proprioception is perhaps one of the most vital components in maintaining balance during sporting activities, which changes ankle position in response to the demands placed by the complex upper body tasks seen in elite sports [5].

Fencing is an open combat sport with complex footwork that requires strength, flexibility and stability of the lower extremities. It is a sport of agility, involving movements of acceleration and braking, changes of direction, uncertainty of space and time, with tasks that are physically and cognitively demanding [10, 11]. According to research on fencing injuries, time loss injuries in international fencing is very low, with sprains and strains of the lower limbs being the most common cause. Men are much more vulnerable than women. Sprains amounted to 41% and strains to 20% of the lower extremity injuries (72%), with ankle sprains (25%) being the most common individual injury [12]. Reduced stability and poor balance increase injury rates [13–15]. Therefore, a decrease in balance control could be the reason for these injuries.

Fencing exerts considerable physiological demands on neuromuscular coordination, strength, power, and effect the musculoskeletal system due to its unique asymmetry in movement. Fencers position their leading foot in line with their opponent and their trailing foot at an angle to the lead foot in the classic ‘on-guard’ posture for stability. [16]. This is followed by the Lunge, which is the most common offensive gesture used to reach the opponent. It is distinguished by a forward thrust in which the front foot advances and breaks the movement while the back leg provides stability by contracting concentrically. These movements are unique to each lower limb and necessitate a high level of proprioception that cannot be acquired through regular training.

A range of rigorous exercise therapies administered in a task-specific paradigm have been shown to be useful in improving ankle proprioception. This is thought to happen due to neural mechanisms such as neural learning and plasticity [5]. Individuals with chronic ankle instability demonstrated better dynamic balance, awareness of inversion joint position, and alterations in motoneuron pool activity after a six-week balance training programme compared to healthy controls who did not exercise [17].

App based interactive rehabilitation has the potential to facilitate implementation of effective measures to prevent sports injuries. Virtual reality games have been used previously to train balance and proprioception in the elderly, normal and sporting population and stroke patients [18, 19]. Virtual reality games are engaging and distracting, so the patient’s attention is drawn to the game rather than his or her condition, making exercise more fun and increasing adherence to and completion of fitness and rehabilitation programmes [20]. However, app based interactive training on the sporting population is limited and has never been done in fencing so far. We

Table 1 Distribution and demographics of subjects (N = 10)

Parameters (N = 10)	Mean (SD)
Age (yrs.)	19.30 (1.63)
Height (cm)	170.66 (6.36)
Weight (kg)	58.50 (7.29)
BMI	20.11 (2.22)
Dominant limb length (Right) (cm)	89.80 (3.61)
Non-Dominant limb length (Left) (cm)	89.80 (3.61)

(N) sample size, (yrs.) years, (cm) centimetres, (kg) kilograms

hypothesized that adding a wobble board and game-based exercise program to their regular training would improve their balance ability. The effectiveness of this exercise programme was analysed using the Kinematic Measurement System and lower quarter Y Balance test, before and after the six-week training period.

2 Methodology

2.1 Participants

The Institutional Ethical Committee of Guru Nanak Dev University, Amritsar, granted ethical approval. Ten university level (six male and four female) Fencers, between the ages of 18–23 years (demographic data mentioned in Table 1), injuries to the lower limbs have not occurred in the previous six months and not undergoing rehab during the study period, volunteered to participate in the study. Fencers who played below inter college level, players with a history of a lower limb injury within the previous six months or undergoing rehabilitation during the study period were excluded from participating in the study. Each participant was given an information leaflet and was required to sign a consent form before participating in the study.

2.2 Testing Procedure

Lower quarter Y Balance test: Three tape measures, one anterior to the apex and the other two at 135° in the posteromedial and posterolateral directions from apex, were secured to the laboratory floor, to assess reach directions. In the anterior, posteromedial, and posterolateral directions, the reach distance was measured from the most distal point of the stance foot's toes to the most distal point of the reach foot's toes. The absolute reach distance was determined using the average reach of three trials in each direction and leg. The distance between the ASIS and the medial malleolus was measured in supine to assess limb length. To express relative reach percentage, the

absolute reach distance data was divided by the limb length and multiplied by 100 [21, 22]. To eliminate the shoes' enhanced balance and stability, all of the tests were conducted barefoot. The second toe's intersection of the YBT's reach direction lines was located at the anterior margins of the participants' feet. Before completing two test trials in each direction on each leg, a member of the study team demonstrated the test to the subject. Each individual was given a two-minute rest interval after completing the test trials before performing three trials in each direction. To minimize diurnal variance, the tests were conducted at the same time every day. During the test, if the participant take the hands off their hips, did not return to the beginning position, exerted weight through the reach foot so as to increase reach distance, positioned the reach foot on either side of the line, or raised or shifted the stance foot, the trial was judged invalid, and the data discarded. The subject was given another chance [23]. Longer reach distance in all directions is an indicator of good balance.

Kinematic Measurement System Balance and Stability Test: Subjects completed a 20-s wobble board balancing test using the KMS system (Innervations, Muncie, IN, USA). Under the wobble board, a metal plate connected to the computer hardware was inserted. The number of contacts between the wobble board's perimeter and the metal plate were counted by the programme. The athlete was instructed to balance the board off the ground, once they were standing on it with comfortable foot placement, for 20 s. Before the subject performed two practise trials, a member of the research team demonstrated the test. This test was performed three times with a 20-s break between each trial [24]. The results (average number of contacts) were recorded. A lower number of contacts made over the course of the test is considered a sign of good balance.

2.3 Training Protocol

A free to download and use smartphone-based app (Classic Labyrinth 3D Maze by Cabbie Games (Classic Labyrinth 3D Maze—The Wooden Puzzle Game, Developer—Cabbie Games, Version: 7.7) was used along with a wobble board. It is a gyroscope-based tilt/roll the ball into the target puzzle game. It was downloaded into a Samsung M30 phone which was fixed onto the wobble board. The wobble board was a standard USI board which consisted of a wooden disk 18″ in diameter and a 4″ hemisphere attached to the bottom. The sphere allowed 17° of angulation in all directions approximately. Participants were instructed to progress through the levels, using their feet to control the motion of the ball, to solve the puzzle while balancing on the wobble board. They were instructed to either complete 2 levels a day or at least stay on the board while trying to complete a level for 3 min, 3 sets every day, with 1 min rest period between sets, 5 days a week for 6 weeks [17]. Participants completed levels 1–26 (excluding levels 15 and 16 which all the participants were unable to perform and were skipped) in this 6-week period.

2.4 Statistical Analysis

The SPSS version 17.0 for Windows software was used for statistical analysis (SPSS Inc., Chicago). The data is presented as a mean standard deviation. To compare the outcomes before and after the intervention, a paired sample t-test was applied in this study. The significance threshold was set at 0.05.

3 Results

The means and standard deviations of all the recorded variables are reported in Tables 2, 3 and 4.

On both legs, significant variations in absolute reach distance and relative reach percentages of lower quarter YBT were seen in all directions (Tables 2 and 3). Participants reached further on both right ($P < 0.005$) and left ($P < 0.005$) legs after training than before, indicating a significant improvement in balance ability.

The number of contacts made in KMS decreased significantly post training ($P < 0.005$) compared to pretraining, indicating an improvement in balance ability (Table 4).

Table 2 Mean, standard deviation of absolute and relative reaches in anterior, posteromedial, and posterolateral directions pre and post training in Y Balance test of the dominant leg

Parameters		Dominant limb (Right)	
		Pre-training	Post training
		Mean (SD)	Mean (SD)
Anterior	Absolute reach	94.19 (11.279)	106.90 (11.673)
	Relative reach	104.66 (9.298)	118.87 (10.376)
Posteromedial	Absolute reach	98.71 (5.747)	114.76 (7.938)
	Relative reach	109.69 (8.487)	127.82 (7.664)
Posterolateral	Absolute reach	108.27 (9.061)	122.43 (6.223)
	Relative reach	120.69 (10.796)	136.48 (7.952)

Table 3 Mean, standard deviation of absolute and relative reaches in anterior, posteromedial, and posterolateral directions pre and post training in Y Balance test of the non-dominant leg

Parameters		Non-dominant limb (Left)	
		Pre-training	Post training
		Mean (SD)	Mean (SD)
Anterior	Absolute reach	91.83 (9.942)	103.33 (10.878)
	Relative reach	102.11 (8.411)	114.93 (9.554)
Posteromedial	Absolute reach	97.96 (8.126)	110.36 (8.052)
	Relative reach	109.21 (9.983)	122.93 (9.733)
Posterolateral	Absolute reach	106.33 (6.350)	117.63 (6.655)
	Relative reach	118.50 (7.319)	131.49 (7.462)

Table 4 Mean, standard deviation of number of contacts made pre and post exercise intervention on KMS Balance and stability test

Parameters	Pre-training	Post training
Number of contacts	Mean (SD)	Mean (SD)
	42.99 (7.089)	(7.668)

4 Discussion

The purpose of this study was to investigate how effective a six-week smartphone app-based workout programme would be to improve ankle balance and proprioception in fencers. There was a considerable increase in absolute reach distance and relative reach percentage in all three directions of the lower quarter YBT and a significant reduction in the number of contacts made in KMS after the intervention period. These findings suggest that there is an improvement in balance and ankle proprioception after the intervention.

Wright et al. [25] investigated the effectiveness of an eight-week wobble board balance intervention in reducing chronic ankle instability symptoms and re-sprain. The major outcome of interest was patient-centred measurements. At weeks four and eight of the intervention, they discovered an improvement in global assessment of function. The patients who started with the least stability improved the most, and these gains lasted for at least 6 weeks after intervention. Linens et al. [26] used a wobble board rehab approach for clinical ankle instability to quantify improvements in clinical deficits. To assess static and dynamic balance, researchers utilised average number of errors in the foot lift test, average reach distance normalised to leg length in anteromedial, medial, and posteromedial orientations of the star excursion balance test, hop test, and fastest time in figure of eight hop test. The researchers discovered

that employing a wobble board as a single intervention improved both static and dynamic balance deficits in chronic ankle instability. Cruz-Diaz et al. [27] determined the effectiveness of a 6-week balance training programme on patients with persistent ankle instability. They found that the balance training group improved significantly in all directions of SEBT after the intervention. The results of this study support the findings of prior investigations, demonstrating that using a wobble board enhances balance and proprioception in fencers.

Lower quarter YBT is used as a functional movement test that predicts injury risk in athletes. This study shows a significant improvement in the absolute reach distances in all reach directions and relative reach percentages normalized to limb length of the lower quarter YBT which are in accordance with the findings of Gonell et al. [28], who examined the relationship between dynamic balance and lower quarter YBT performance in soccer players. Soccer players who scored lower than the average in each reach direction were twice as likely to be injured, according to the study. After the intervention, there was a considerable improvement in the absolute reach distance and relative reach percentage parameters of the lower quarter YBT, which may be considered an indicator of improved balance ability.

In many rehabilitation and training programmes, to enhance balance, unstable platforms like as wobble boards, Swiss balls, and other equipment are often used. Kim et al. [29], compared the effectiveness of ankle strengthening exercises to combined muscle strengthening exercises and proprioceptive exercises to a control group in those with functional ankle instability. There was a significant improvement in the Cumberland ankle instability tool scores post four-week intervention period in the group with combined strengthening and proprioceptive program compared to only muscle strengthening group. This study's findings also imply that a proprioceptive wobble board only training program could improve proprioception in fencers and has the potential to be used in rehabilitation for ankle sprains.

App-based rehabilitation programmes take advantage of video games' intrinsic incentive potential by allowing players to handle a game using a wobble board, allowing them to complete needed exercises while playing Nilsson et al. [30], and Nilsson and Serafin [31], concluded that using these games ensured correct ankle training and motivated the participants intrinsically to complete the rehabilitation program. The strength of the current study is that a smartphone app was used in conjunction with a regular wobble board to train balance. The participants readily participated in the study due to this unique approach. They were better motivated to complete the training program.

5 Limitations

The study's weaknesses include the use of a small sample of fencers and the lack of a control group. As a result, when applying the findings to other sports, caution should be exercised. Because of the ongoing epidemic, participants were not followed up with after the study was completed.

6 Conclusion

The findings of this study suggest that adding game-based exercises into a regular training regime can improve balance and reduce the risk of ankle injuries in Fencers. It might also increase the active participation of the players in the exercise program which could be an added advantage to prevent the ankle injuries. The future studies can be directed to explore the effectiveness of inculcating such game-based exercises in the training programs with larger sample size and diverse sports.

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Conflict of Interest The authors state that they have no competing interests.

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Fatigue Analysis of Recreational Road Cyclist in Terms of Blood Lactate Concentration and Nutritional Intake

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Abstract Blood lactate concentration is one of the most often measured parameters during performance testing of athletes. The purpose of the study was to measure the serial change in the rate of blood lactate concentration in response to the sequential period of cycling. Seven male road cyclists volunteered to be subject in the study. Subjects participated in a 200 km cycling event. Their anthropometric measurement, nutritional intake (three consecutive days), and blood lactate concentration was measured. Their mean age was 38.6 ± 8.7 years, body height 170.9 ± 4.6 cm; body weight was 74.1 ± 7.2 kg with 25.4 ± 2.1 (kg/m^2) BMI and 24.9 ± 3.2% fat percentage. The subject's blood sample was measured through finger-stick (capillary) blood sampling by using an automated blood lactate analyzer. Lactate measurement was made four times: at rest, immediately after the event, 5 min, and 20 min of passive recovery. The study has shown that participants resting LA (2.2 ± 0.9 mmol L^{-1}) was fall into normal range whereas with the passive recovery there was a gradual increase in their blood lactate concentration (5.6 ± 2.9 to 9 ± 3.5 mmol L^{-1}) up to 20 min of recovery time. The mean energy intake day before the event and during the event was less than recommended level by ICMR. Hence it can be concluded that less nutritional intake during and before cycling event might be the cause of less energy production and depletion of muscle glucose which might lead to more lactate accumulation in the muscles during the recovery period.

Keywords Lactate concentration · Nutrition intake · Passive recovery

1 Introduction

Blood lactate concentration is one of the most often measured parameters during exercise testing as well as during performance testing of athletes. Road cyclist reported to perform a large volume of cycling specific endurance training, which can contributes to the production and accumulation of blood lactate. Accumulated blood lactate after any high intensity exercise decreases blood pH, increases muscles stiffness which

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causes pain in the muscle and leads towards low performance. Fatigue can also be subject of response for prolonged cycling. Sometimes the cyclists might experience failure in some physiological function because of shifting of metabolism from aerobic to anaerobic and counter product that working muscle slows its capacity for more work [35]. During long distance cycling, lactate decreases the activities of both the phosphofructokinase (PFK) and hexokinase enzymes [27, 28]. Accumulation of lactate and development of fatigue can be related with nutritional intake. Proper nutritional intake store energy for physical performance and delayed fatigue during intense and prolonged physical activity. Therefore taking insufficient carbohydrate before work can result in gradual depletion of glycogen store. Generally the cyclist like cross country, marathon runner and road cyclist, require 4000–6000 kcal/day in the form of dairy product, grains, vegetable, meat products, fat, and oil [31]. Reduction of body stores of carbohydrate and blood glucose is related to the perception of fatigue and the inability to maintain high-quality performance. However, dietary intake can use to determine the blood lactate accumulation in prolonged exercise. The lactic acid removes slowest at rest and very quickly during the active recovery [30]. The main objective of the present study was to measure serial change in the rate of blood lactate concentration in response to sequential period of cycling in relation with their nutritional intake.

2 Method

Seven male recreational cyclists volunteered to take part in the study. All the subjects were introducing to the aims & objective of the study. Consent before testing was taken from all the participants.

2.1 Event

Two hundred kilometer cycling event was organized by Hisar Roadies and participant volunteered for the study. The event was divided into 3 parts i.e. 50-100-50 km. In the first part subject covered 50 km and took 15 min break, in second part they covered 100 km and took 20 min break and in the third part they covered last 50 km and reached to starting point.

2.2 Subjects

All subjects were outfield cyclist, having continuous cycle practice and minimum cycling experience of two year. Their mean age was 38.6 ± 8.7 years, body height 170.9 ± 4.6 cm and body weight was 74.1 ± 7.2 kg, which was almost similar (height

178 ± 4.8 cm and weight 72.5 ± 6.6 kg on average) with a study by McLean and Parker on elite Australian track cyclists [29]. The subjects rested night before to be completely fit and ready for the event.

2.3 Measurements and Test

The obtained reactance and resistance values as well as data on subjects' age, sex, body height, body weight, fat percentage, body density, body surface area, lean body mass (LBM), BMI, and resting metabolism were measured. Body height of the subjects was determined to the nearest 1 mm using an anthropometric scale. The weight, BMI, fat% and resting metabolism of the subjects was measured by BIA system (Omron body composition monitor, HBF-375 karada scan) with the measurement error of 0.5 kg. BF% was calculated from the impedance value and the pre entered personal data [24]. Body fat% was also measured by using similar method used by Rauter et al. in a study on young male road cyclists [36]. BF% was transformed to density using Siri's equation [37]. Body surface area (BSA) was estimated through applying height and weight using the equation of Dubois and Dubois [6].

2.4 Food Intake

To collect data concerning food intake, three-day food record was employed to improve the reliability of mean food intake data. Questionnaire was prepared to record their pre-race, during-race and post-day dietary intakes. Dietary intake was quantified using household measurement (1 teaspoon, 1/2 cup, 1 slice of bread, etc.), weight (grams), and volume (250 ml milk, juice). On race day, cyclists were asked to record their prerace and during the race meal, to recall what they ate, describing the quantity and type of product (e.g. a banana, 400 ml of juice, chocolate bar etc.). For nutrient calculation, the Nutrify India Now (NIN) app version number 2.0 by ICMR-NIN was used [18].

2.5 Blood Lactate Sampling

The blood lactate concentration was measured through finger-stick (capillary) blood sampling. Briefly, 0.2 μL of blood was collected before being analyzed using an automated blood lactate analyzer (EKF Diagnostics Lactate Scout 4).

2.6 Lactate Test Protocol

Blood sample was collected in two phases: resting and immediate after activity. Resting sample had taken before the event. There was no lactic acid analysis in between the first two half. Second lactic acid test was done immediate after third half, 5, and 20 min, in their passive recovery. This LA detection method corresponded well with the planned sample collection protocol by Hermansen et al. and Ohkuwa et al. [13, 30].

2.7 Handgrip Strength Measurement

The grip strength of both right and left hands was measured by using a digital handgrip dynamometer (Takei 5401) in standing position. Hand was in downward direction with shoulder adducted [14] and elbow in full extension, dynamometer was held freely without touching the subject's trunk. Maximum force was put on the dynamometer for 3–4 s. Measurements were taken three times from both sides of the hands at resting condition and after the completion of the event, average of the three measurements was calculated and value was recorded in kilograms.

2.8 Statistical Analysis

Analyses were conducted using MS Excel of Windows 7. Data were presented according to descriptive statistics (Means ± SD). Furthermore, pearson correlation coefficient was used to find the relation among the anthropometric and biochemical variables [7]. The alpha value was set at 0.01 and 0.05 to determine the highly significance and significance, of the correlation between variables using critical values for Pearson's correlation coefficient.

3 Result

3.1 Anthropometric Description of Participants

Table 1 showed the descriptive statistics of the subjects. Their age average is 38.60 ± 8.70 years, height average is 170.9 ± 4.6 cm, and weight average is 74.10 ± 7.20 kg. The average BMI of the cyclist was 25.4 ± 2.1 (kg/m^2) which classified as overweight category [32]; similar finding was recorded by Kesavachandran et al. among the male residents [25]. The percentage body fat was calculated 24.9 ± 3.2% with body fat weight 18.5 ± 3.4, and lean body mass 55.50 ± 5 which higher than average fat

Table 1 Anthropometric profile of the subjects

Anthropometric variables	Mean ± SD
Age (Year)	38.6 ± 8.7
Height (cm)	170.9 ± 4.6
Weight (kg)	74.1 ± 7.2
BMI (kg/m^2)	25.4 ± 2.1
Fat%	24.9 ± 3.2
Body density (D)	1.8 ± 0.2
Fat weight	18.5 ± 3.4
Lean body mass	55.5 ± 5.2
Body surface area (m^2)	1.9 ± 0.1
Resting metabolism	1654 ± 112.6
Basal metabolic rate	1681.8 ± 126.3
B-RHGS (kg)	41.30 ± 5.77
A-RHGS (kg)	38.09 ± 5.46
B-LHGS (kg)	38.40 ± 3.64
A-LHGS (kg)	32.20 ± 7.37

B = Before activity, A = After activity, RHGS = Right handgrip strength, LHGS = Left handgrip strength

percentage (24.00%), fat weight (13.68 ± 3.59) and lean body mass (44.50 ± 3.97) [37]. Average body density and body surface area (BSA) was 1.80 ± 0.20, and 1.90 ± 0.10 m^2 respectively. The study further showed that the handgrip strength of the cyclist before and after the whole cycling event. Before the event means grip strength of the right and left hand was 41.30 ± 5.77 kg and 38.40 ± 3.64 kg; decreases 38.09 ± 5.46 kg and 32.20 ± 7.37 kg after the whole event respectively. After the whole event, there was a total 7.78% and 16.15% decrease in the right hand and left-hand grip strength respectively, reduce in grip strength (dominant hand = 33.6 ± 8.9 kgf vs. 29.1 ± 9.0 kgf; non dominant hand = 33.8 ± 9.9 kgf vs. 28.1 ± 8.1 kgf) was also recorded by the Honorato et al. (2021) in a study on young male judo athlete and untrained individuals [15].

3.2 Correlation Among Anthropometric Data

The statistical analysis index correlation coefficient was used to measures the linear correlation among the variables. The equation of $0 < |r| < 1$ indicates the linear correlation between two variables. The more |r| approaches 1, the closer the linear correlation and more |r| approach 0, the weaker the linear correlation between the two variables. The value 0.00–0.30 (0.00 to −0.30) have negligible correlation, 0.30–0.50 (−0.30 to −0.50) have low positive (negative) correlation, 0.50–0.70 (−0.50 to −0.70) have Moderate positive (negative) correlation, 0.70–0.90 (−0.70 to −0.90) have High

positive (negative) correlation [16, 17]. Table 2 showed the positive and negative correlation among the anthropometric and metabolic variables. Age was negatively correlated with anthropometric and metabolic variables such as height, weight, body density, LBM, BSA, RM and BMR. Height, weight and BMI have shown moderate to high positive correlation LBM, BSA, RM and BMR ranging from r = 0.61 to 0.98. Weight was moderately related with height and highly related with BMI. Fat % and body density have negligible to low positive relation with LBM, BSA, RM and BMR but both have highly positive to highly negative correlation with fat weight. Fat weight, LBM, BSA, RM and BMR have low positive to highly positive correlation among each ranging r = 0.37 to 0.94. Hand grip strength before and after activity showed low, negligible and negative relation with anthropometric and metabolic variables, but there was a high positive correlation between each hand before and after the activity [11].

3.3 Nutritional Intake of Participants

At any level of preparation and competition, proper diet is essential. Both professional elite cyclists and recreational cyclists should eat a well-balanced diet of enough calories to fulfill their energy requirements.

Athletes who consume less than 2000 cal per day can struggle to meet their nutritional requirements, especially for iron and calcium. An insufficient diet can also cause weight loss, glycogen depletion, and dehydration. Dietary strategies can increase or retain the body's carbohydrate reserves for high training performance such as road cycling and other endurance events [12]. Table 3 showed mean energy intake was high in D-3 (2214.2 ± 185.7 kcal) followed by D-1(1678.5 ± 59 kcal and D-2 (1045.9 ± 78.3 kcal), which was below than estimated energy requirement (3470 kcal/d) [19]. Carbohydrate in day after the event was calculated higher (355.5 ± 36.1 gm) than D-1 (181.4 ± 7 gm) and D-2 (121.8 ± 5.9 gm). As the table revealed that during the event (D-2) mean energy and carbohydrate intake was lowest; it can be associated with the muscle glycogen depletion and reduced blood glucose concentrations which might affect the muscle glycogen storage and can leads to muscle fatigue during and after event [22, 23]. Table further showed that protein intake was above the recommended level on day before (81.3 ± 8.5 gm) and after the event (71.6 ± 7 gm) but slightly lower in D-2 (50.3 ± 1.2 gm); similarly fat intake was also above the recommended level on day before (69.7 ± 5.2 gm) and after the event (56.2 ± 5.7 gm) but slightly lower in D-2 (39.7 ± 2.5 gm).

3.4 Blood Lactate Concentration (mmol L^{-1})

Heart rate and blood lactate (LA) are the two most relevant metrics used by sports science to measure aerobic strength in relation to sub maximal exercise. Lactate is

Table 2 Analysis of correlation of anthropometric data

	Age	Ht	Wt	BMI	Fat %	D	Fat wt	LBM	BSA	RM	BMR	B-RHGS	A-RHGS	B-LHGS	A-LHGS
Age	–														
Ht	−0.471	–													
Wt	−0.001	0.651*	–												
BMI	0.214	0.233	0.857**	–											
Fat%	0.549	0.040	0.301	0.520	–										
D	−0.572	−0.040	0.746**	−0.524	−0.995**	–									
FAT WT	0.403	0.364	0.746**	0.825**	0.858**	−0.857**	–								
LBM	−0.269	0.665*	0.897**	0.646*	−0.150	0.135	0.376	–							
BSA	−0.048	0.830**	0.910**	0.659*	0.388	−0.380	0.759**	0.764**	–						
RM	−0.112	0.737**	0.982**	0.752**	0.148	−0.157	0.630*	0.949**	0.918**	–					
BMR	−0.473	0.854**	0.876**	0.610*	0.023	−0.021	0.475	0.904**	0.857**	0.920**	–				
B-RHGS	−0.725**	0.027	−0.387	−0.417	−0.398	0.391	−0.523	−0.192	−0.387	−0.337	−0.008	–			
A-RHGS	−0.469	−0.035	−0.322	−0.247	−0.032	0.012	−0.238	−0.290	−0.325	−0.338	−0.068	0.916**	–		
B-LHGS	−0.422	−0.028	−0.115	0.018	0.077	−0.087	−0.049	−0.128	−0.175	−0.159	0.072	0.834**	0.949**	–	
A-LHGS	−0.536	0.220	0.047	0.055	0.005	−0.036	−0.018	0.077	−0.015	0.032	0.282	0.836**	0.925**	0.937**	–

**Correlation is highly significant (positive or negative) at the 0.01 level, *Correlation is significant (positive or negative) at the 0.05 level

Ht = Height, Wt = Weight, D = Body density, LBM = Lean body mass, Wt = Weight, BSA = Body surface area, RM = Resting metabolic rate, BMR = Basal metabolic rate, B = Before activity, A = After activity, RHGS = Right handgrip strength, LHGS = Left handgrip strength

Table 3 Mean nutritional intake of three consecutive days

Nutrient	RDA/EAR	Day before event (D-1)	During event (D-2)*	Day after event (D-3)
Energy (Kcal)	3470 (kcal/d)	1678.5 ± 59	1045.9 ± 78.3	2214.2 ± 185.7
Carbohydrate (g)	130 (g/d)	181.4 ± 7	121.8 ± 5.9	355.5 ± 36.1
Protein (g)	54 (g/d)	81.3 ± 8.5	50.3 ± 1.2	71.6 ± 7
Fat (g)	40 (g/d)	69.7 ± 5.2	39.7 ± 2.5	56.2 ± 5.7

*RDA/EAR = according ICMR 2020 report, *D-2 only during event intake was calculated
*RDA = Recommended Daily Allowance; EAR = Estimated Average Requirement

a biochemical marker that indicates a muscle's ability to engage in athletic activity and can also determine the anaerobic threshold is measures [20]. The increase in blood lactate levels above the normal range of 5–10 mg or 0.5–1 mmol L^{-1} in 100 cc blood can prevents muscle contraction and accelerates fatigue [19, 25]. In the present study blood lactate (LA) concentration was taken before and after the whole sports event. Figure 1 showed the serial change in the blood lactate concentration before and after the event. Mean resting LA (mmol L^{-1}) was recorded 2.2 ± 0.9, and blood concentration immediate after completion of third phase was increased 5.6 ± 2.9 mmol L^{-1} which was 156.9% increase from the resting level. Similar finding was reported by Dong Jun etal (2016) in a study to examine whether blood lactate levels at rest and after all-out exercise depend on body fat percentage [5]. In the recovery

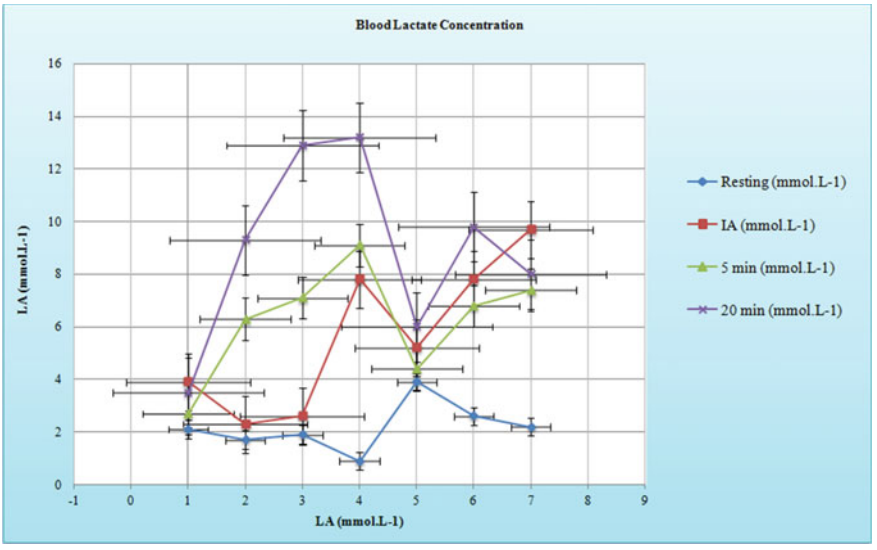

Fig. 1 Blood Lactate concentration (mmol/l): Resting, IA (Immediate after activity), 5 and 20 min of recovery

phase, LA (mmol L^{-1}) has increased up to 6.3 ± 2.1 mmol L^{-1} in first 5 min and 9.0 ± 3.5 mmol L^{-1} up to 20 min of passive recovery.

Increase in blood lactate concentration is depending on the work rate, exercise duration, intensity and training [1, 24]. In a study Menzies et al. revealed that it after the prolonged exercise would take around 32 min to blood lactate concentration to returned in baseline values even after active recovery and in the present study subjects were at passive recovery state therefore it might be the cause of continuous increase in blood lactate level up to 20 min after activity [30].

3.5 Correlation Among Anthropometric, Nutritional Intake and Lactate Concentration

Table 4 has showed the multiple correlations among nutritional intake during the event, blood lactate concentration before and after the event, and anthropometric parameters of the individual.

Table showed both energy and carbohydrate have low negative relation with RM and BMR; both also showed moderate negative to low negative relation with anthropometric variables (range r = −0.604 to −0.447). Date further revealed that resting LA (mmol L^{-1}) was negatively correlated with energy and carbohydrate but in contrast lactic acid IA (mmol L^{-1}), 5 min (mmol L^{-1}), and 20 min (mmol L^{-1}) have shown positive correlation with energy and carbohydrate, therefore intake of energy and carbohydrate can be related with the production of the LA before and after the activity. RM and BMR were positively correlated with weight and height but both were showed significantly negative relation with lactic acid IA (mmol L^{-1}). The resting LA (mmol L^{-1}) has low positive relation with anthropometric variables and moderately negative relation with 5 min (mmol L^{-1}), 20 min (mmol L^{-1}). LA after activity and in recovery have shown negligible to high positive relation range r = 0.030 to 0.897. Significantly high correlation was found between LA in 5 and 20 min of recovery. Anthropometric variables (weight, BMI, fat% and fat weight) have high negative to moderate positive correlation with IA (mmol L^{-1}), 5 min (mmol L^{-1}), 20 min (mmol L^{-1}) range from r = −0.833 to 0.574.

4 Discussion

The purpose of this study was to analyze serial change in the rate of blood lactate concentration in response to sequential period of cycling in respect with nutritional intake. The sample of the research consist seven male recreational cyclists. The subjects had the experience of participating in many long distance cycling events and they volunteered to take part in the study.

Table 4 Correlation among anthropometric, nutritional intake and lactate concentration

	Energy	Carbohydrate	RM	BMR	Resting LA (mmol L^{-1})	IA (mmol L^{-1})	5 min (mmol L^{-1})	20 min (mmol L^{-1})
Energy	–							
Carbohydrate	0.992**	–						
RM	−0.463	−0.462	–					
BMR	−0.576	−0.552	0.920**	–				
Resting LA (mmol L^{-1})	−0.656*	−0.586	0.249	0.585	–			
IA (mmol L^{-1})	0.295	0.322	−0.877**	−0.738**	0.004	–		
5 min (mmol L^{-1})	0.581	0.622*	−0.463	−0.641*	−0.564	0.449	–	
20 min (mmol L^{-1})	0.542	0.586	−0.151	−0.394	−0.568	0.079	0.897**	–
Age	0.207	0.153	−0.112	−0.473	−0.806**	0.030	0.573	0.574
Weight	−0.516	−0.529	0.982**	0.876**	0.206	−0.833**	−0.481	−0.193
BMI	−0.447	−0.503	0.752**	0.610*	0.030	−0.585	−0.517	−0.332
Fat%	−0.502	−0.511	0.148	0.023	0.012	0.146	0.117	0.035
Fat wt	−0.590	−0.604*	0.630*	0.475	0.087	−0.342	−0.148	−0.051

**Correlation is highly significant (positive or negative) at 0.01 level, *Correlation in significant (positive or negative) at 0.05 level, RM = Resting metabolic rate, BMR = Basal metabolic rate, IA (mmol L^{-1}) = Blood lactate concentration immediate after event, 5 min (mmol L^{-1}) = Blood lactate concentration after 5 min, 20 min (mmol L^{-1}) = Blood lactate concentration after 10 min

In the present study body composition were measured by BIA (Bioelectrical impedance analysis) technique. BIA based on principle of resistance to electric current to LBM and body fat [30]. In the present study, anthropometry profile of the subjects of shows many similarities to the elite track cyclists. BMI and fat% above range can be indicator of adipose tissue storage and increase in adipose tissue may cause the production of more lactate than with less adipose tissue but in some sports extra body weight proves to be an advantage, in which body stability is important [7]. In the present study statistical correlation revealed that body weight, BMI, fat % and fat weight having positive correlation but body density (D) have shown negative correlation with these variables except body weight. Faria mentioned that body fat might restrict the capacity for prolonged cycling by increasing the energy cost of riding, as body weight proportional to energy cost of cycling; overweight cyclist can expend more body reserves to carry extra weight but increase in the adipose tissue might be the cause of more lactate production [8, 34].

The ability to predict accurately the relative leanness or fatness of the cyclist is required if proper nutritional guidance is to be offered. Individual participating in endurance training, can consume 5000 kcal, consuming adequate nutrients may promote training and heighten the performance [2]. Proper energy intake directly affects the energy production and reduces fatigue. As per the recommendation by ICMR report (2020) estimated energy requirement (EER) per day is 3470 kcal/day [19], but in the present study mean energy intake was below than recommended level. Study further showed on event day (D-2) consumption of CHO (121.8 ± 5.9 g) was lower than RDA (130 g/day) but on D-1 (181.4 ± 7 g) and D-3 (355.5 ± 36.1 g) CHO consumption was above RDA. For prolonged exercise carbohydrate rich food might be helpful for the generation of energy and to balance the nutritional requirement during and after the activity. Data further revealed that in the three consecutive days participants didn't take balance diet therefore improper nutritional intake during and before cycling event might be the cause of less energy production and depletion of muscle glucose which leads to the accumulation of metabolite in the muscles. As carbohydrate play a key role in supporting physical activity because of the need to maintain blood glucose concentration [35] and produce energy more efficient manner than fat and protein [10]. Stored carbohydrate (glycogen) form glucose, oxidized to CO_2 and water (aerobic glycolysis or TCA) and formed more ATP, but insufficient amount of carbohydrate fails to produce energy, which can leads to muscle fatigue [10]. Study further revealed that energy, carbohydrate intake was lower than recommended level by the cyclist on the event day (D-2), which lead to depletion of muscle glycogen during prolonged cycling, accumulate lactate and cause exhaustion [10, 38]. The lactate level found be 2.2 ± 0.9 mmol L^{-1} at baseline was fall around the normal rang 0.5–2.0 mmol L^{-1} [9], and with passive recovery there was gradual increase (5.6 ± 2.9 up to 9.0 ± 3.5 mmol.L^{-1}) in the blood lactate concentration up to 20 min of recovery (approx. 43.15% increase). Therefore data can conclude that after prolonged activity, passive recovery can cause the continuous increase in blood lactate concentration. Devilin et al. (2014) also conclude that blood lactate cleared faster during active recovery than passive recovery and in compare with low intensity activity, high intensity activity decrease lactate concentration more rapidly [4].

During prolonged cycling, glycogen store can be decrease in the working skeletal muscles. The glycogen stores of human skeletal muscle are rapidly consumed during sub maximal cycling requiring 60–80% of aerobic power [3]. Carbohydrate rich diet enhances resynthesis of the muscle glycogen store within 46 h and carbohydrate free diet with same caloric content, re-synthesis after 8–10 days [33]. Therefore resynthesis rate of muscle glycogen depends on the balanced diet.

5 Conclusion

It may be concluded from the present study that, nutritional intake have different effect on LA (mmol L^{-1}) production before and after the activity. Prolonged activity can decreases glycogen store in the working muscles. Because the glycogen store depends on the diet or nutritional intake of the individual, balance diet requires fulfilling the body energy requirement to sustain the work for long period and also helps to reduce fatigue.

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Musculoskeletal Discomfort Faced by Interior Design Students During Online Learning

Himani Shah

Abstract Musculoskeletal disorders are prevalent in young adults in the present times. A major section of this age group are the students pursuing higher education. In the current pandemic situation due to COVID-19, the students have been forced into attending classes through online mode and so the infrastructure available at home may not be optimal ergonomically, leading to musculoskeletal discomfort amongst the students. In Interior Design course, the students are required to do practical work in a sitting position using the furniture available at home. They are also required to attend classes through computers, tablets and smartphones, which can also lead to musculoskeletal discomfort. As these students are exposed to the risk of developing musculoskeletal disorders, the present study was conducted with objectives (a) to gain insight into working methods and home workspace of the students, (b) to identify incidence of musculoskeletal discomfort experienced by interior design students during online learning and (c) to find out the perceived causes of musculoskeletal discomfort by the students. The sample of the study was 77 under-graduate students pursuing Interior Design course and data was collected using questionnaire. The findings of the study revealed that these students are in need of proper workspace and work environment at home, they need guidance in optimizing there working methods and developing proper work schedules and lastly, they need awareness regarding maintaining correct postures during sit-down work as well as corrective measures for optimizing their current work-station at home.

Keywords Work-station at home · Optimal workspace · Perceived causes of musculoskeletal discomfort · Musculoskeletal discomfort · Online learning · COVID-19 pandemic

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1 Introduction

Musculoskeletal disorders are prevalent in present times. The major cause of this is work-related load on the musculoskeletal system. This system consists of the muscles, tendons, the skeleton, ligaments, cartilage as well as nerves. A health issue in any of these parts is called a musculoskeletal disorder. This disorder can be slight and temporary but also can be disabling and irreversible. It begins with discomfort, which is experiencing ache, pain, discomfort and/or numbness in neck, shoulder, upper back, lower back, elbows, hands, wrists, thighs, knees, ankles and or feet. This discomfort can cause musculoskeletal pain when experienced over longer period of time. Eventually, it causes musculoskeletal disorders which turn into permanent injuries or health issues. Generally, these issues are observed in occupational work environment but nowadays it is prevalent in the young adults also. A major section of these young adults are students pursuing higher education. The workspace and work environment provided in higher education institutes may sometimes not be optimized for use by a diverse group of students. This can cause musculoskeletal discomfort and pain to them. The learning process of the Interior Design field requires the pursuant students to use different methods for preparing their designs. An Interior Designer is required to work on designing of spaces and its various components using different tools and devices. Preparation of such designs can be done by hand drafting using various tools as well as through aid of computer software for which optimized workspace and furniture is required. Interior Designer works majorly in sitting position while creating designs, as well as, standing and leaning over the desk, if furniture is not adjustable. This can cause postural problems leading to musculoskeletal discomfort. An institutional classroom may provide the optimal workspace and furniture design to the students but this may not be the case at home. The current pandemic situation, due to COVID-19, has forced the students into attending classes through online mode and so the infrastructure available at home may not be optimal ergonomically, leading to musculoskeletal discomfort amongst the students.

A review of researches has shown that in a past few years studies have focused on load faced by school students in carrying the school bags [2, 3, 6, 13], leading to musculoskeletal pain and disorders. There have been studies focused on students in healthcare studies where musculoskeletal issues have been found in higher intensity, especially in dentistry and nursing students [1, 5, 7, 10, 11]. A study on posture related discomfort in university students showed that awareness on ergonomic requirements and gender of the student had no impact on health of their musculoskeletal system. It was actually determined by duration and type of computer use [12]. In a study related to online learning, students perceived organisational ergonomics to be of utmost importance in tertiary education delivered using teaching platforms [8]. Research on non-classroom teaching during COVID-19 of the university students indicated decrease in musculoskeletal discomfort due to increased physical activities [9]. Several researches have been found with focus on musculoskeletal discomfort, pain and disorders in students at school level as well as university level with focus

on weight of bags to be carried, use of computers/laptops and design of furniture. There are studies focused on students in healthcare education and dentistry but no studies were found regarding students of Interior Design and availability of proper infrastructure at home for online learning, in light of COVID-19 pandemic. Thus, this research was conducted with objectives: (a) to gain insight into working methods and home workspace of the students, (b) to identify incidence of musculoskeletal discomfort experienced by interior design students during online learning and (c) to find out the perceived causes of musculoskeletal discomfort by the students.

2 Methodology

The present study focuses on describing various attributes of selected population in relation to musculoskeletal discomfort. Thus, this study is descriptive research. A questionnaire was developed and circulated for the purpose of data collection. The questionnaire, firstly, aimed to collect information from respondents regarding their practices in use of tools and devices for online learning and, secondly, regarding experiencing any musculoskeletal discomfort. It was divided into 2 sections wherein Sect. 1 focused on collecting background information of the sample and their practices in relation to online learning with regards to use of space, furniture and electronic devices. It included inquiries such as duration of use of devices, availability of dedicated space for online learning, disturbances in learning online from home, etc. The alpha coefficient (Cronbach's Alpha) for the four items was 0.885, suggesting that the items had relatively high internal consistency. Section 2 asked about any incidence of musculoskeletal discomfort felt by the sample and their perceived reasons for cause of the same. In order to investigate musculoskeletal discomfort experienced by the respondents, the Nordic Musculoskeletal Questionnaire was adopted, as it allows to identify discomfort as perceived by the sample [4]. The questionnaire was developed using Google Forms and circulated via email to under-graduate students pursuing Interior Design course in Vadodara City, Gujarat, India. 155 students received the questionnaire out which 77 responded. Thus, a sample of 77 respondents was included for the study using purposive sampling technique. Students facing musculoskeletal discomfort due to chronic disease, any surgery or due to an accident, were excluded from the study. For the present study, the terms online learning refers to online classes plus subsequent assignments to be attempted and submitted by the students, through online mode, for discussion and assessment.

3 Findings

Following results were revealed through the study:

3.1 Background Information

The background information included various demographic details of the respondents. Out of 77 respondents 80.30% were female students and 19.70% were male students. 55.80% of the respondents were from first year, 35.10% students were from third year and 9.10% students of second year participated in the study. The average age of the respondents was 20.48 years. The height of the students ranged between 4 feet 9 inches and 6 feet. The average weight of the respondents was 57.23 kgs. 64.90% respondents belonged to a nuclear family and 35.10% belonged to a joint family. The annual income of the students' family ranged from ₹1 lakh to ₹25 lakhs. The average floor area of residence of the students was 960 ft^2.

3.2 Working Methods and Home Workspace of the Students

Data related to working methods of the students, and availability as well as condition of the workspace was collected. 32.50% of the students used only hand drafting for interior design practical work, 20.80% did only computer aided work and 46.80% used both methods for doing their work. Out of 77 respondents 66.20% of the students used a combination of smartphones and laptops for their work. 55.80% of the respondents spent more than 2 hours at a stretch while doing college work. 26.70% of the students engaged in online learning and college work for 3 hours per day and 21.30% worked for 4 hours per day. 18.18% students spent more than 5 hours per day doing college work (see Fig. 1).

36.80% of the respondents did not have a dedicated space for engaging in online learning at home. The space dedicated to online learning was also being used by other family members in case of 74% of the respondents, for other work. 50.60% of the respondents did not have furniture customized to their anthropometric as well as work requirements. 14.30% of the students did not have sufficient lighting, 15.60% respondents did not have proper air-circulation and 23.40% of the respondent had

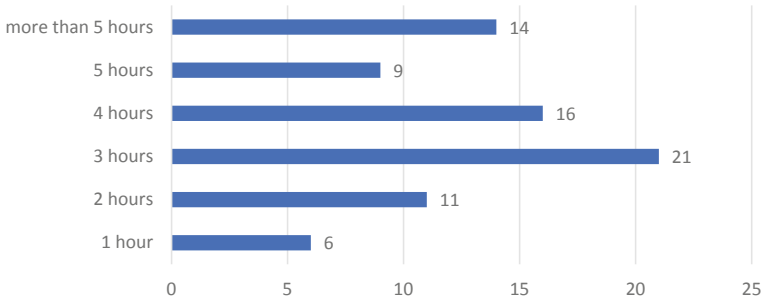

Fig. 1 Distribution of respondents according to number of hours spent per day for the purpose of online learning

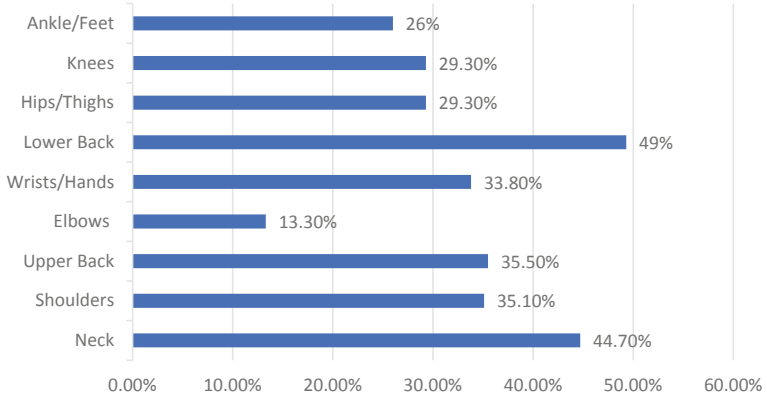

Fig. 2 Percentage of respondents prevented from performing routine tasks due to ache, pain, discomfort, numbness experienced in the last 12 months

no temperature control in their workspace. 53.20% of the respondents experienced disturbances during online learning. Through an open-ended question, the major causes for disturbance were reported to be issues with internet connectivity, internal and external noises and disturbances due to shared spaces.

3.3 Musculoskeletal Discomfort Experienced

It was found that majority of the respondents experienced musculoskeletal discomfort in neck, shoulders, upper back and lower back. 71.40% of the respondents reported to have experienced discomfort in neck in the past 12 months and 44.70% were hindered from continuing day-to-day activities due to it (see Fig. 2).

68% of the respondents faced discomfort in the lower back and 49% of them were unable to perform daily tasks due to it. 37.70% of the respondents still experienced discomfort in neck, 33.33% in the shoulder and 48.60% in lower back, in last 7 days before responding to this research (Table 1). Table 1 presents prevalence of musculoskeletal discomfort experienced by the respondents.

27.30% students sought medical/clinical assistance for musculoskeletal discomfort.

3.4 Perceived Causes of Musculoskeletal Discomfort

The respondents were asked, through an open-ended question, to list down causes of musculoskeletal discomfort as perceived by them. 68.60% of the respondents reported that improper sitting postures were major cause of their discomfort. 42.90%

Table 1 Incidence of musculoskeletal discomfort

Parts of the body	Percentage of respondents that experienced ache, pain, discomfort, numbness at some point in the last 12 months (prior to response to this study) (%)	Percentage of respondents that experienced ache, pain, discomfort, numbness at some point in the last 7 days (prior to response to this study) (%)
Neck	71.40	37.70
Shoulders	55.60	33.33
Upper back	47.90	26.30
Elbows	22.70	15.80
Wrists/Hands	45.90	23
Lower back	68	48.60
Hips/Thighs	34.70	22.70
Knees	37.30	22.70
Ankle/Feet	24	24

of the respondents were facing discomfort due to awkward work timing, 45.70% had improper furniture and 47.10% reported cause of discomfort to be being involved in familial duties and activities. 31.40% of the respondents felt discomfort due to inadequate space, 32.90% due to lack of privacy and 27.10% because of inefficient work devices. 28.60% of the respondents perceived discomfort to be caused due to physical health issues, 30% due to higher noise levels and 34.30% due to the requirement to help with domestic household tasks. Some other causes listed by the respondents were issues with internet connectivity, financial burden, mental health issues, inadequate lighting and air-circulation and other family issues. The respondents believed and reported these reasons to be a cause for their musculoskeletal discomfort.

4 Discussion

Musculoskeletal discomfort can lead to musculoskeletal disorders. Identifying the issues and implementing corrective measures for the same, is of utmost importance. The existence of musculoskeletal discomfort amongst young adults is a cause of concern, especially, for students in higher education as they are yet to embark upon their professional journey. While, the higher education institutes strive to provide efficient workspace and work environment to the students, it cannot cater to requirement of each and every individual. In the same way, home is shared by multiple family members and cannot be completely designed to the need of one individual. The COVID-19 pandemic has forced individuals to work from home. The students pursuing higher education are also required to engage in online learning from home. Every student may not have optimal infrastructure for studying from home. Students pursuing interior designing, as under-graduate programme, require proper workspace

and environment. The current study has revealed that a great number of students are facing musculoskeletal discomfort while engaging in online learning and subsequent course related work. They have lacking workspace with incorrect furniture and non-conducive work environment at home. The students have also reported several causes for discomfort which are indicators of several issues related to online learning from home, due to family demands, and various problems of the family and home.

5 Recommendations

The present study was focused on identifying incidence of musculoskeletal discomfort experienced by interior design students during online learning, gaining insight into working methods and home workspace of the students and finding out the perceived causes of musculoskeletal discomfort by the students. The result of the research described and reported the afore-mentioned data. A further exploration into extent of musculoskeletal discomfort and finding specific causes is recommended. Postural risk assesment for respodents can be done. As an extension of the current study, a case-study can be conducted of selected samples having greater musculoskeletal discomfort through which specific interventional suggestions can be provided. A detailed observation of the work-station at home along with assessing ergonomic requirements of the selected sample can be conducted in addition to the current study and as a result of which ergonomic design solutions can be given to the students. A similar cross-sectional study can be done for under-graduate students from other higher educational programmes.

6 Conclusions

The study concluded that these students are in need of proper workspace and work environment at home, they need guidance in optimizing there working methods and developing proper work schedules and lastly, they need awareness regarding maintaining correct postures during sit-down work as well as corrective measures for optimizing their current work-station at home.

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Evaluating Indoor and Outdoor Thermal Comfort Parameters Affecting Work Environment of Railway Pantry Car

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Abstract Indian Railways is one of the largest passenger transport networks in the "world" covering almost all parts of the subcontinent. Pantry car is an integral part of the railway, which provides food to the passengers during the journey. This study aims to evaluate the "indoor and outdoor thermal comfort parameters" and working conditions in the kitchen of the Indian "railway pantry car". The field measurement was carried out during the summer season on six "Indian Railway Pantry Car Coaches (IRPCs)". The "indoor and outdoor environmental parameters" were recorded during different cooking periods; "breakfast, lunch, snacks, and dinner" inside the pantry car. The consequence of this study revealed that the "indoor thermal comfort parameters" like; "wet-bulb temperature, mean radiant temperature, air temperature, relative humidity" were higher as compared to outdoor parameters except for air velocity. Most of the time, indoor parameters were higher during the lunch and snacks periods while lower at the breakfast period. Similarly, indoor Heat Index (HI) value was recorded higher than the outdoor. The indoor HI values range were found to be (40–58 °C), which indicated "danger to extreme danger" work condition. These outcomes will help to understand the "working environment of the railway pantry car kitchen". Further, data measurements during winter and other seasons could be used to predict the thermal environment of the "pantry car".

Keywords Environmental ergonomics · Thermal comfort · Railway · Pantry car

1 Introduction

Thermal comfort expresses the "condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective assessment" as per the "ANSI/ASHRAE Standard-55" [1, 2]. There are six significant factors that affect human thermal comfort, which four "environmental factors"; "air temperature, mean radiant temperature, relative humidity, air velocity" and two "personal factors"; "clothing level and metabolic rate" [2–5]. Generally, thermal comfort research has

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been carried out in the (a) building environment like; offices, apartments, schools, etc., (b) transports like; cars, buses, trains, airplanes [6–12]. While few types of research have been focused on the kitchen atmosphere such as; "rural households, restaurants, cafeterias, hotels, and hostels", in India and abroad [13–17]. Although, very few studies have concentrated on the "kitchen of the railway pantry car". Initially, a pilot study was accompanied by Alam et al. [18] on the "railway pantry car kitchen" using subjective and objective assessment with a few sample size. This study's authors suggested that railway pantry cars' "indoor environment" is "hot and humid" during cooking. The railway pantry car has an important contribution to serve food to the passengers, which is an "integrated part of every long and short distance train" [19]. At present, "338 pantry car coaches" are moving with trains. A one pantry car has 3–5 "chefs", 40–50 "waiters", and 2–3 "managers/staff" [20]. In India, there are two categories of pantry car coaches available such as (a) air-conditioned-AC (b) non-air-conditioned-Non-AC [4, 21]. But according to the earlier investigation by Alam et al. [4] suggested, no difference was found between AC and Non-AC while working (cooking) inside the pantry car. In both categories of pantry cars, chefs are using common appliances viz; "gas stove," "heater," "pressure cooker," "oven," "kettle," "deep fryer," "soup warmer" others too [22, 23]. These appliances produce heat and moisture while cooking inside the "pantry car", because of which the inner atmosphere of the pantry car becomes "hot and humid" [23]. This kind of "hot and humid" atmosphere significantly affects thermal comfort, associated with occupant's productivity and work efficiency.

It is clear from the above discussion that thermal comfort is compulsory for the "kitchen of the railway pantry car". Hence, this study aims to evaluate the "indoor and outdoor thermal comfort parameters" and working conditions in the kitchen of the Indian railway pantry car.

2 Method

2.1 Sample and Period

The current study was carried on six "Indian Railway Pantry Car (IRPC)" during field measurement. The data was collected during the "summer season" in August 2018. Due to "safety and security" purposes, the study period was set to 15 days. During the "summer season", data was recorded in two diverse climatic regions; "humid and subtropical" and "tropical wet and dry," as per the "Koppen climate classification system", but the climactic analysis is not discussed in this study.

2.2 Objective Measurement and Heat Index (HI) Estimation

During the objective measurement, "indoor and outdoor thermal parameters" were recorded. The thermal parameters like; "wet-bulb temperature (Twb), air temperature (Ta), relative humidity (RH)" were measured with the support of "kestrel anemometer-4500". Although air velocity (Va) was measured with support of thermal anemometer testo-405i. Similarly, with the support of a "6-in. black-globe thermometer, globe temperature (Tg) was measured". The thermal parameters like "Twb, Tg, Ta, RH, Va" was measured at "1 ft. (0.3 m) near the workstation (cooking zone)" and "43 in. (1.1 m) above the workstation floor in the pantry car kitchen" as per the ASHRAE-55 [14]. The mean radiant temperature (Tmr) was determined by applying Eq. (1).

$$t_{mr} = \left[\left(t_g + 273\right)^4 + \frac{1.1 \times 10^8 v_a^{0.6}}{\varepsilon D^{0.4}} \times \left(t_g - t_a\right) \right]^{1/4} - 273 \tag{1}$$

where ε = emissivity of the globe surface "has assumed as 0.95".

In this research, "indoor and outdoor thermal parameters" were recorded at the various cooking periods such as; "breakfast—7:00 am, lunch—11:30 am, snack—4:00 pm, and dinner—6:30 pm". The outdoor measurements were recorded near the kitchen window of the pantry car when trains stopped short period at the platform. While both "indoor and outdoor thermal parameters" were recorded with the duration of 10–15 min and 5–10 min, respectively.

This study Heat Index (HI) was used to recognize the work condition of the "pantry car during cooking times". The HI index values were noted with the support of "kestrel anemometer-4500". Table 1 shows the "HI" temperature limits and working conditions.

Table 1 HI temperature ranges and work condition

Celsius (°C)	Fahrenheit (°F)	Work condition
27–32	80–90	Caution
32–41	90–105	Extreme caution
41–54	105–130	Danger
Over 54	Over 130	Extreme danger

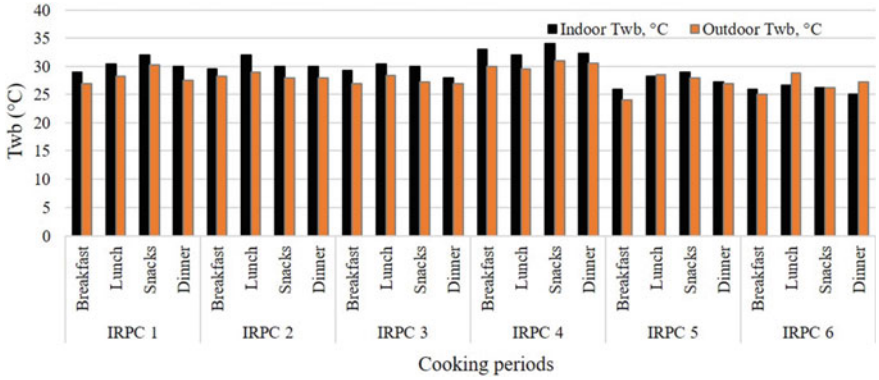

Fig. 1 Indoor and outdoor "wet bulb temperature distribution at the different cooking periods"

3 Result and Discussion

3.1 Indoor and Outdoor Environmental Condition During Cooking Periods

According to the literature, four influential environmental parameters affect thermal comfort indoor and outdoor conditions, such as; "air temperature, mean radiant temperature, relative humidity, air velocity" [1, 2]. This study considered all four thermal comfort parameters, including wet-bulb temperature during various "cooking periods like breakfast, lunch, snacks, dinner".

Figure 1 shows the "indoor and outdoor" wet-bulb temperature (Twb) distribution at the various cooking periods. As presented in the graph, the "maximum and minimum" values of indoor "Twb" were found at snacks (34) and dinner (25 °C), respectively, with an mean value of 29.42 °C. In contrast, the maximum and minimum value of outdoor "Twb" was found at snacks (31 °C) and breakfast (24 °C), respectively, with an average value of 28 °C. These consequences indicated that indoor "Twb" were found to be higher than outdoor. Similarly, Fig. 2 illustrates the indoor and outdoor mean radiant temperature (Tmr) distribution at the various cooking periods. The "maximum and minimum" values of indoor "Tmr" were found at snacks (37 °C) and dinner/breakfast (28 °C), correspondingly, with a mean value of 32.44 °C. Simultaneously the maximum and minimum value of outdoor "Tmr" was found at snacks (34 °C) and lunch (15.4 °C), respectively, with an average value of 23.84 °C. The comfort range of "Tmr" for indoor dwellings should be 18–27 °C [24]. However, the measured value of the indoor "Tmr" of this study was observed beyond the recommended range. Figure 3 depicts the indoor and outdoor "air temperature (Ta) distribution at the different cooking periods". The "maximum and minimum" values of indoor "Ta" were found at snacks (37 °C) and breakfast (26.1 °C), respectively, with an "average value" of 32.34 °C. Similarly, the maximum

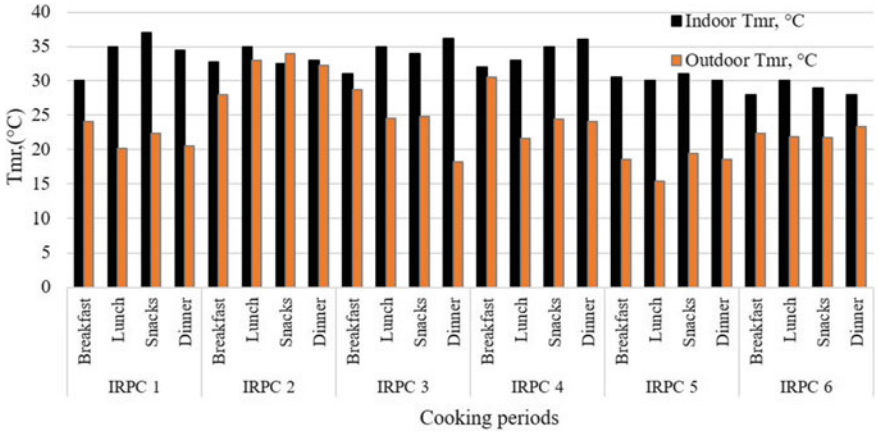

Fig. 2 Indoor and outdoor "mean radiant temperature distribution at the different cooking periods"

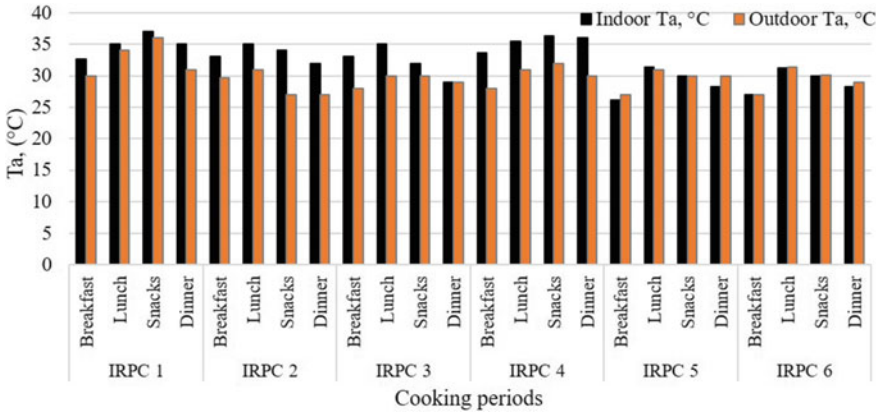

Fig. 3 Indoor and outdoor "air temperature distribution at the different cooking periods"

and minimum value of outdoor "Ta" was found at snacks (36 °C) and breakfast (27 °C), respectively, with an average value of 29.95 °C. The "National Building Code of India" suggested the comfort temperature limit of the workers for "summer season (23–26 °C)" and "winter season (21–23 °C)" [18]. Accordingly, the ASHRAE-55 suggested the comfort "Ta" for the "summer season 24.5–27.0 °C", and the "winter season 19.5–22.5 °C" [21, 23]. Whereas in this investigation the value of "Ta" did not follow the suggested level.

Figure 4 exhibits the "indoor and outdoor relative humidity (RH)" appearance at the various cooking periods. The "maximum and minimum" values of indoor "RH" were found at "lunch" (87%) and "breakfast" (69%), correspondingly, with an average value of 75.75%. At the same, the "maximum and minimum" value of outdoor "RH" was found at "breakfast" (96%) and snacks (66%), respectively, with

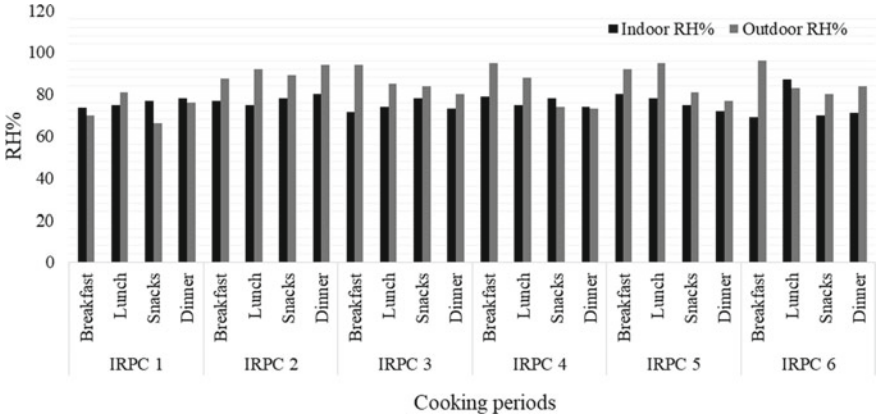

Fig. 4 Indoor and outdoor "relative humidity distribution at the different cooking periods"

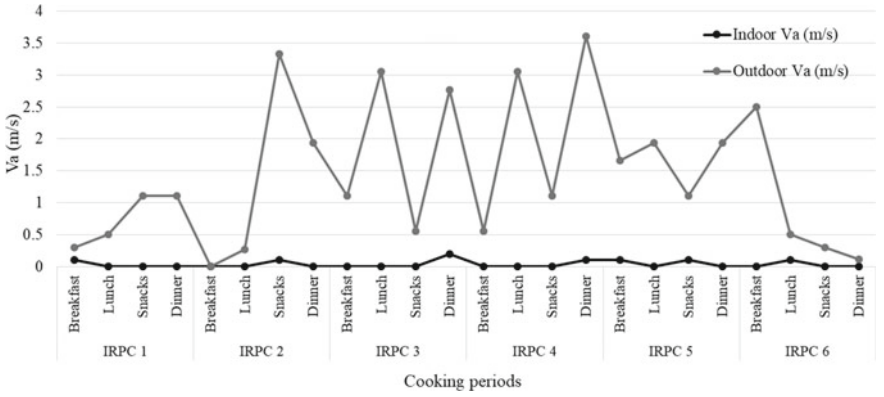

Fig. 5 Indoor and outdoor "air velocity distribution at the different cooking periods"

an average value of 84.01%. The RH value between "30–60%" was confirmed for comforts [25]. The current study measured values of RH has illustrated completely diverse phenomena. Similarly, Fig. 5 presents the indoor and outdoor air velocity (Va) distribution values at the "various cooking periods". As shown in the graph, the maximum values of indoor "Va" were recorded at dinner (0.2 m/s) and the average value 0.03 m/s. Most of the time, indoor "Va" values were recorded very less (0.00 m/s), except few cooking periods. In contrast, the maximum and minimum value of outdoor "Va" was found at dinner (3.61 m/s) and breakfast (0.00 m/s), correspondingly, with an average value of 1.43 m/s. Whereas for the "summer season", the value of "Va" is "<0.25 m/s" as directed by ASHRAE-55 [20].

In this study, the heat index (HI) was incorporated to recognize the work environment during cooking in the "kitchen of the railway pantry car".

Figure 6 represented the indoor and outdoor heat "HI" distribution values at the

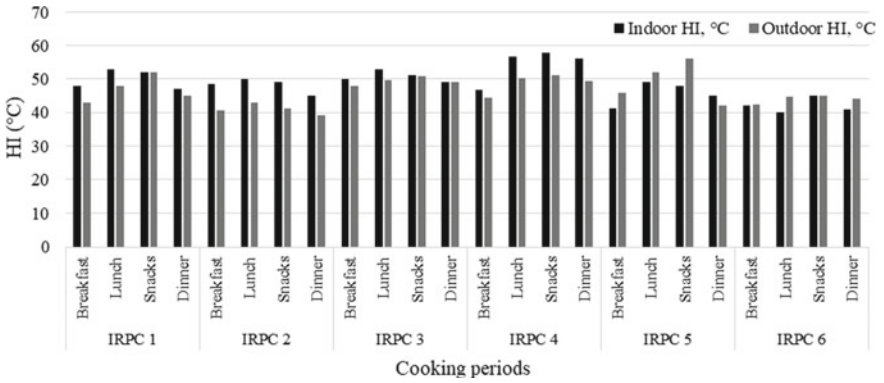

Fig. 6 Indoor and outdoor heat index distribution at the "different cooking periods"

various "cooking periods inside the pantry car". As shown in graphs, the "maximum and minimum" values of indoor "HI" were determined at snacks (58 °C) and lunch (40 °C), correspondingly, with an average value of 48.52 °C. The work exposure was indicated "danger to extreme danger" conditions. Likewise, "maximum and minimum" values of outside "HI" were determined at snacks (56 °C) and dinner (39.2 °C), correspondingly, with an average value of 46.55 °C. The work exposure was indicated "extreme caution to extreme danger" conditions. The measured values of indoor "HI" value were found to be higher than the outdoor condition, which addressed the pantry car thermal environment not appropriate for occupants.

4 Conclusions

The current study goal to appraise the "indoor and outdoor thermal comfort parameters" and working conditions in the railway pantry car during various cooking periods; breakfast, lunch, snacks, dinner. In this study, field measurements were made during the summer season. This research showed that the "indoor thermal parameters" such as; "Twb, Tmr, Ta, RH" were found higher compared to outdoor parameters except for "Va". Simultaneously, it was observed that indoor thermal parameters were higher during the lunch and snack periods while lower during the breakfast period. Accordingly, the recorded indoor "HI" value was found higher than the outdoor. The indoor HI values range was found to be (40–58 °C), which showed the work exposure limit "danger to extreme danger". These effects will help to recognize the current state of the "railway pantry car kitchen". In this study, only objective measurements were carried during the summer season using the "HI" index. In further analysis, winter and other seasons data need to be determined, as well subjective measurement.

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Sustainability a Tool for Employment Opportunities

Abhishek Singh, Pratul Chandra Kalita, and Raksha Singh

Abstract Environment concerns are on the top priority by the Global policymakers (United Nations (2002) Report of the world summit on sustainable development. Johannesburg [1]). The environmental concerns are also emphasized by the urban populations of the world, who are struggling for clean and pure air. The urban population with access to the internet is actively participating in the various environmental campaigns on social media but are unable to make any impact on the real ground. On the other hand, the farmers in the rural sector are having seasonal employment, and the remaining part of the year they move to cities for other job opportunities. So we have used the Business model canvas tool to understand the gap and requirement of the current scenario. As per the analysis, we have formulated a business model in which all the available government and forest lands will be used for plantation drive for a greener future. The people from town and cities who are not having land for plantation can use government land for the purpose and at the same time employment opportunities for the rural population for nurturing the plants is also generated. The project is a two-way business model, where the rural population will earn living and the urban population will earn carbon credits (the currency of the future). Apart from monetary benefits, this project will help in spreading awareness for environmental concerns.

Keywords Sustainability · Business model · Environment conservation rural development

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1 Introduction

India being the largest democracy and is also the fastest growing economy of the world. The race for development has prompted India for smart city projects, mega infrastructure projects, economic corridors, trade routes (inside as well as international), Special economic zones, etc. A mass urbanization and Industrialization movement is going on across the nation. These projects have great potential for strong economy, employment opportunities, improvement in living standard, latest technology deployment and many more advantages.

This development comes with a cost. Majority of population of country like India is agriculture based. Even if the entire nation is converted to high tech smart city people are going to need food to survive. As stated by [2] "The rapid urbanization around the globe is exploiting the natural resources exponentially, may it be water, air, land or minerals", this has led to severe damage to the environment and have disturb the ecological balance. The green belts are destroyed, the fertile lands are used for infrastructure development and the waste infertile lands are left unused. Since the cities or urban settlement also need water and electricity for sustaining hence all the fertile river beds are being converted into cities.

Sustainable development not only in terms of economy but also in terms of environment and the increasing socio-economic gaps of the society. In a study [7] concluded that any product or system development must be done with more awareness regarding complex life cycles, multiple stakeholders, societal issues, liability issues, product issues, and so forth for better results. Hence we have tried to understand the demography of the society and how it can be used in the favour of our aim and objective. Similarly [8–11] have emphasized that sustainability is the key to revitalize the social capital.

2 Literature Review

The literature review of this project is the data collected from the census and planning commission surveys. So we will discuss these data in three segments—

- Population Distribution in each employment sector.
- Contribution of each sector in GDP of India.
- Comparison of population distribution and their contribution to GDP of India.

2.1 Population Distribution in Each Employment Sector

As per [3] majority of Indian working population is living in the rural areas and are contributing to the largest workforce base (53% of total population) in Agriculture sector, whereas the construction and manufacturing industry provides employment

to 22% of working population, remaining all sectors can be considered in the service sector constituting of 25% of total population. The trend of the working population in 1950 was 85% in agriculture and only 5% employment was in other sectors. But along the years the workforce migrated to urban setup to be a part of modern life style and contributing to manufacturing and service sectors.

2.2 Contribution of Each Sector in GDP of India

As stated in [4, 5] the contribution of Agriculture sector in the GDP of India is only 17% of total GDP; whereas Industrial sector contribution is nearing the double of the agriculture sector i.e. 30% of total GDP.

Sectors like tourism and miscellaneous services are also part of service sector. Hence the total of service sector contributes 53% of total GDP of the nation. So from the data mentioned in [4, 5] it is clear that India is now a service based economy in which Industries and agriculture plays a supporting role.

2.3 Comparison of Population Distribution and Their Contribution to GDP of India

Table 1 gives a clear relation between the population distribution and their contribution to the GDP of India. For a fairer distribution of resources and livelihood opportunity the ration of GDP contribution (%)/working Population distribution (%) should be closer to 1. The farther the score move away from 1, greater will be the inequality in the society.

Agriculture being the largest job provider of the nation is unable justifies its contribution to the GDP. This result in underpaid agricultural work force who struggle to fulfill their basic needs. This is the major part of the India population.

Whereas the Industrial or manufacturing sector are doing fairly well, the percentage of working population involved is contributing little more in GDP as compared to the value of their percentage of population involved in the sector.

Table 1 Comparison sheet of working population and GDP contribution

Sectors	Working population (%)	Contribution to GDP (%)	GDP contribution (%)/working population (%)
Agriculture	53	17	0.32
Manufacturing/Industry	22	30	1.36
Service	25	53	2.12

But when we analyze the service sector they are doing exceptionally well, the population involved in this sector is considerably low and their contribution to GDP is very high. This service sector is the most lucrative sector of the nation. They enjoy all the luxuries of the life. The demand of unorganized sector products and services (including Agricultural products) by the users in the urban areas are significantly high as per the study published by [6], but the contribution in GDP is dropping year after year due to the entry of organized tails and E Tails.

3 Problem Statement

A survey was conducted among 150 daily wage workers working in the city of Guwahati to understand their background. It was found that 70% of workers are seasonal workers and work when there is no farming season and remaining time they work in their farms. Where as out of 30% who work in the urban setup throughout the year, are actually semiskilled or skilled labours, who have left farming long back. Since, they are getting better earning than the farming and are on demand in the construction and other industries.

Farming is a seasonal occupation and the gaps in the farming season forces the farmer to look for other alternatives of employment. While working in industries and urban setup fetch them good money and stability. This shift in the behavior is causing a mass shift of rural population to urban setup. Because of the above trends we are already facing major problems such as:

1. The socio-economic status gap between the agriculture based population and urban population is increasing by leaps and bounds.
2. This will lead to a major shift of rural population to urban setup and eventually the self-sustaining agriculture industry which is the largest employer of Indian workforce will be adversely affected.
3. The farmers are selling their land and settling in urban setup for good quality of life and standard. These lands are being used for infrastructure development.

The number of farmers working in the agriculture industry is one of the largest segments of Indian work force. The workers in the urban setup are already facing unemployment issues and urban setup is not having enough job opportunities to cater the needs of all the farmers migrating to urban setup. This is going to create a massive disbalance in the working classes at the same time will hamper the agricultural output. We need to have a sustainable model which can support the farmers and the societies with low income in terms of additional employment in their own land and they are not forced to migrate to other places for livelihood.

4 Research Gap

Huge gaps between communities with economic barriers and well to do society segments are created which is increasing day by day. The increasing urbanization is pressurizing the rural setup to migrate to the urban setup for attaining good lively hood. This trend is destroying the agriculture and other rural services. People living in rural setup should get sufficient employment and survival opportunity in their own habitat to have an organic growth of the society. There is a huge gap in the employment opportunities in the rural sectors.

Eco-sustainability is also neglected in the race for development. Now sustainability level of the environment has passed beyond repair, major transformation in the policies and the level of awareness is required to address the issue. Only awareness is not going to get any impact on the ground level. If we really want to do something concrete in resolving these issues or at least initiate something effective. Then we need to design some tool for people to interact with nature more to understand its importance and to feel its presence and absence.

4.1 Research Questions

- How can we generate better lively hood opportunity for rural sector?
- How can we bond people living in cities with nature and environmental issues?
- Can we make a tool or a strategy to give platform to the people living in city to actually work on the issues of environment rather than just debating on the topic?

4.2 Aim

The aim is to develop a business model which can support the villages and people in agriculture background with additional employment opportunity. At the same time develop some green belts to support natural habitats.

4.3 Objectives

- To generate employment opportunities in rural sectors of the society.
- To initiate a movement to develop green belt patches in waste lands to support natural habitats.

5 Methodology

For making a sustainable business model steps being adopted are mentioned below:

- Identification of the resources available.
- Orientation of resources with respect to our objective—Basic concept.
- Identify the customers need.
- Business model flow chart.
- Funding for sustainable business model.
- Analysis of business proposal.

5.1 Identification of the Resources

The resources available with us are the waste and infertile land mass. These land mass are neither used for agriculture or any type of urban or industrial development. Plants saplings can be easily developed by the farmers in their waiting time and with the help of some botanical expert mass numbers of sapling can be easily produced in limited time. Water is the only concern which is to be tapped, stored and utilized as per our requirement. So we have to make a sustainable micro water cycle to fulfil our needs.

We will need large work forces for developing the land, farmers, craftsmen and semiskilled workers to bring this project to reality. Along human resource, Social media network and transportation network will also play an important role for our business model to survive and sustain. These two will be the main life line on which the entire business model depends.

5.2 Orientation of Resources with Respect to Our Objective—Basic Concept

Our main concern starts with environmental impacts; hence with the objective of reviving the habitat the basic requirements will be land, water and plants. Availability of land being a major can be addressed by simply switching the frame of fertile or valuable land with infertile and waste land. So the first step would be identification of waste lands which do not have any significant value for others. The plant sapling farming and water availability will be the part revenue generation schemes to be adopted in this business model.

In case of human resource availability vocational farmers and their teams are available for major part of the years when they are waiting for the crops to mature. India is facing huge unemployment concerns so this business model will help in develop semi skilled work force for all the requirements of our business model.

For any business to be successful it has to develop an awareness model and they should be able to connect with the customer base. The awareness will be spread through social media. In twenty-first century the word trending has more power and popularity than any advertising media. So we will have a social media website linked with our business model with similar platforms like Facebook, Twitter, etc. with our own USP to isolate it from other social web sites.

5.3 Identify the Customers Need

Our objective was to create a balance between the societies with different economic status. So our aim was to generate revenue from the higher and upper middle class society and generate employment opportunities for the under privileged or societies with very low incomes. This clarifies that our customer base will be higher or upper middle class. This class of society has already all the basic needs, security needs, belongingness needs and love needs. So majority of the class are willing to accomplish self esteem needs.

The people from this group of society are aiming for higher education, contributing to the society, aspiring for accomplishments and acceptance by the society. Everyone from this society sector wants to leave their mark in the book of time and be immortal. So we decided to tap this zeal of the society and use it for our objective. The trend of likes, followers, Re tweets, etc. are all exploiting the same zeal of the society for personal profits. So why shouldn't we do it for the environmental and social need of the hour. So we have kept Social network as the core for the entire business expansion campaign and the zeal of humans to be immortal in the book of time as a one of the motive behind our business model.

5.4 Business Model Flow Chart

The project starts with identifying a waste land which can be easily connected with transportation network and water accessibility but it is not mandatory. The top priority is identification of large chunks of waste lands. Then these vocational farmers or unemployed/unskilled sectors are hired for developing the base of the business model. We are proposing a monument of Mother Nature which will be at the centre of the waste land. Which will be the main attraction and from where the spreading of green belts in radial pattern start.

For bringing customers to the site is the main challenge. Modular awareness campaigns will be organized to spread the word. The main objective fed to the customers will be protection of environment and make one self immortal in this monument of Mother Nature with a plant and a WOMB stone. Womb stone will be a stone template on which you can scribe anything you name, quotations, anniversary, birthday or any happy memory which you want to make immortal and fix it next to

the sapling you have planted. The template is named as Womb Stone because it is the birth of your memory and a baby sapling is being planted in the Womb of Mother Earth.

Your name will be there forever and as the plant grows the value and sentiments with your memory will also grow. Then with every sapling you plant, you will get an ID on the social network of Mother Nature. Here you can do everything as in other social networks but you can also track your weekly growth of the sapling, since weekly photographs will be updated online and notification for all the event of the sapling will be intimated to you.

Once the flow of customers will start and the plants will start growing then we will develop resorts and other facilities to promote eco tourism. Then water reservoir and other utilities can also be developed to make it a proper man made heritage site for Mother Nature.

5.5 Funding for Sustainable Business Model

We have identified following options for generating fund for sustainable business model in initial stage:

Nursery, Stone carving, Transportation, Camping, Eco tourism, Resorts, Organic Farms.

6 Detailing of Business Model

As discussed above we are bridging the urban communities with the rural communities to work for a common goal to revive the environment. The limitations on one society are the strength of the other society. Hence, we are designing a system in which both the societies can help each other in their endeavors to achieve a common goal.

As shown in Fig. 1, Urban populations are having capital to invest and environmental awareness but are restrained by shortage of time and land. On the other hand rural population is having sufficient time and land is also available near their habitats. But they are lacking employment opportunities and lively hood for better standard of living. The core value of our business model is to establish Socio-Economic-Environmental balance in the society. We have designed our business model with 5 cores as shown in Fig. 2. In which two are different segments of the society and one is environmental sustainability. The remaining two are the interactions between these three. Both the societies will interact in terms of services being offered here and services taken. The last one is the most important core. It is bonding between the societies and together they work to sustain the environment.

Our entire business model will revolve around these 5 cores that are:

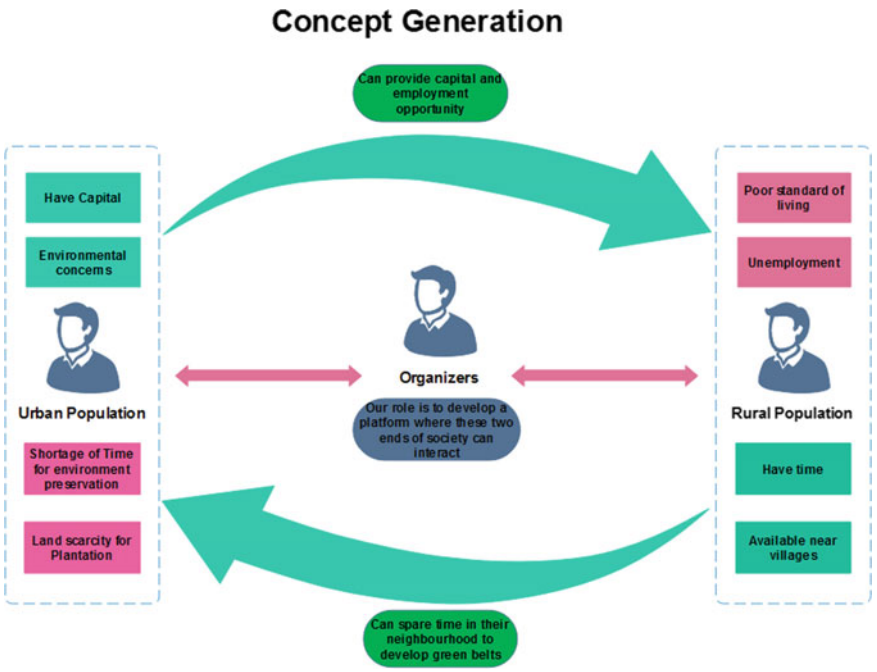

Fig. 1 Concept generation

Urban population: We have considered three segments of the population that is students, working professional, elderly and housewives. We are targeting these three segments for our business model.

Rural setup: We are going to use their space and services. In return we will generate better employment opportunities and improve their living standards.

Environmental sustainability: We will identify the wastelands and try to convert into green belts to revive the natural habitat.

Services: For attracting people from urban setup we need to offer them something which they will be interested in. So we have designed different services for all segments of the society. Our motive is that people from all segments of urban society should have something of their interest in our business model.

Awareness and bonding with nature and society: If we are successful to attract different segments of urban setup to us then we can make them part of our movement to spread the awareness and they can feel more bonded with the nature once they are close to it.

There are multiple employment opportunities to be generated from our business model. It comprises of people with no education to field experts. The mass vacancies will be for farmer and daily labourers. Since we have to keep on converting the

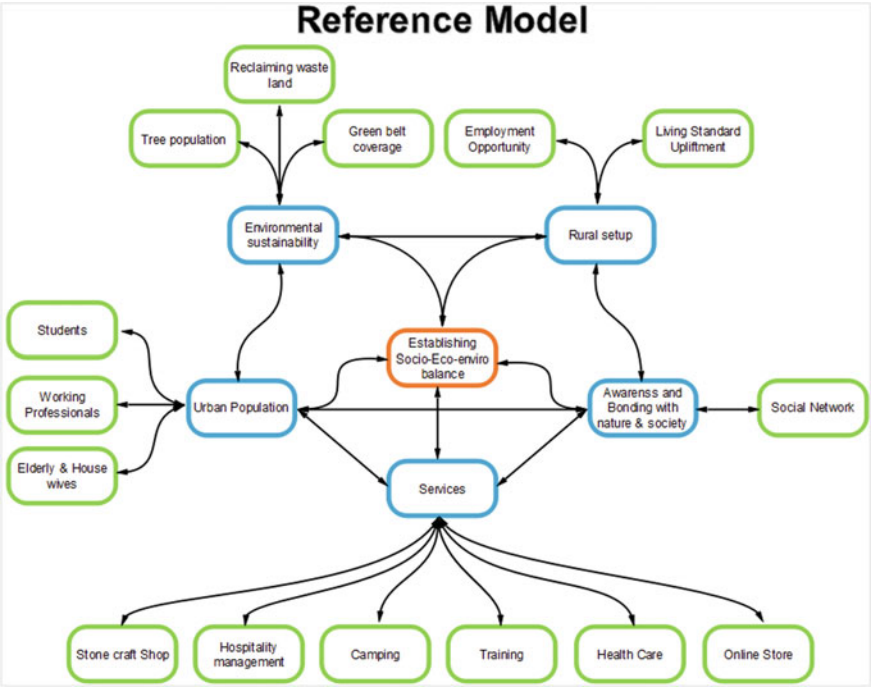

Fig. 2 Reference model

waste land in to green belts by growing plants and maintaining them till they are self sustaining.

Remaining all services mentioned in Fig. 3 is to attract the urban population to the desired locations. In this process the people from villages will be trained for different skills to get better wages and improve in their earning capacity.

People skilled in Sculptures and other creative traditional arts will be required to conduct creativity classes for students. Similarly multiple layers of employment opportunities will be offered like information technology services, hospitality management, logistic services, training experts, farming and many more.

Task Flow for establishing site: For starting the business we need to establish the site. The process starts with identifying large chunks of waste land. So that we have very low value asset and can start with very low investments. We can even tie up with government to develop their waste lands in to spot of tourist destinations. At the same time employment and other value-added services will increase the importance of their low value assets.

Then the designated land will be plotted as per the proposed design. Then we will make the site approachable so that conveyance and transportation services can be used. After that initial establishment like office, kitchen, toilets, water supply, waste disposal, electricity, etc. are to be set up. Then centers for services to be established

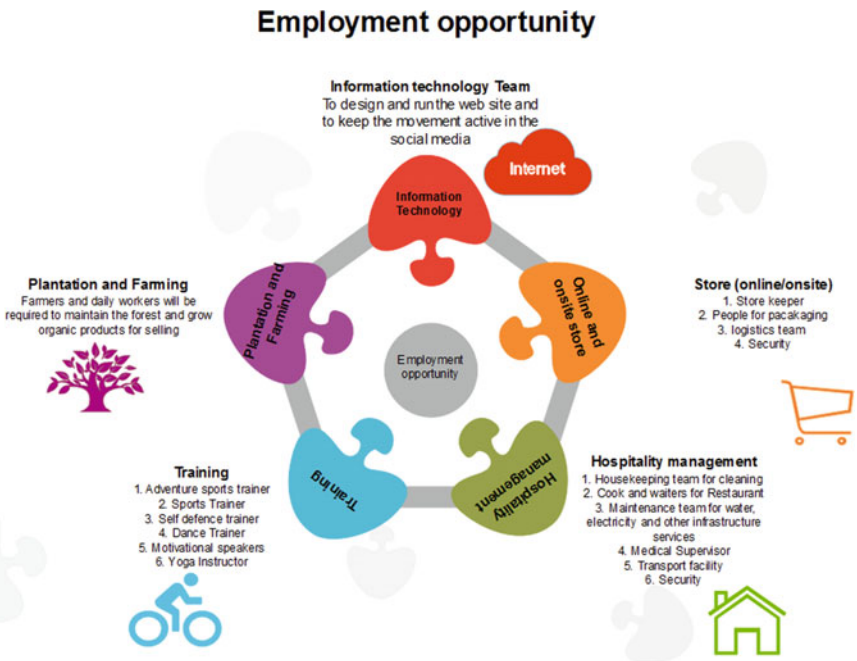

Fig. 3 Employment opportunities

like nursery, workshop, Ninja track, Sports ground, Tents and open theatres, Zip lines, etc. Once the services are ready then maintenance teams are deployed to keep the utilities functional. Since our services are very season specific. So we have decided to develop an organic farm in the waste land to have a supporting business and keep the employees involved and active. Some sustainable hybrid carts [11, 12] have also been developed for selling the organic produce in the local cities.

Website design: We will also have a web site for spreading awareness. The web site will be designed in such a way that it will act as a social network to connect all people with same vision and ambitions. The website will have all the details of our services offered. Individual profiles of member of the group can be maintained. The members can interact with other members of the group and the organizing committee. The members can share their views and pictures and videos of the trip they had and the plants they have planted. Each sapling planted will have a history or a memory tag with it. This memory tag will represent any memory of the member which he wants to be there forever. The member can attach the history with photos and videos in the id of that plant. Each plant will be having designated memory space. So the memory is alive in virtual world and is linked with a plant growing in the physical world. The plant is also marked with a womb stone to have some remarks of that memory in the real world.

Population specific details are available in our website. There is something for every segment of the society to visit. People can explore different events and camps being organized time to time to keep the interest of the people alive.

Online store portal will also be there for people who want to buy organic products and sapling of exotic plants.

Business Model canvas:

To understand the business we have plotted entire concept in this business model canvas. Since we are having multiple facets of the business, so converting the concept in single canvas could have made it very complex and cluttered. So to simplify it we have made two different canvases to explain two different sectors of the business and how they can generate revenue from the customers.

Business Model Canvas I:

The first canvas explains how the plantation of trees as a social movement has a potential to generate a self sustaining model to execute. This part of the business is a nonprofit part of the model. We have to design it in such a way that it will cater as a social obligation of the citizen for the future generations and hence it is a nonprofit business model.

Table 2 Business model canvas I

<table>
<tr><td rowspan="2">Key Partners
1. Nursery
2. A Monument of Nature
3. Maintenance Team
4. Craft workshop</td><td>Key Activities
1. Selling of a sapling or plant
2. Donating it for the environment
3. Maintenance of the plant
4. Stone carving</td><td rowspan="2">Value Preposition
1. Contributing to an environment cause
2. The required support of land availability
3. The time constraints required for nurturing plant will be addressed
4. The memories will be immortal</td><td>Customer relations
1. Help desk
2. Online Support
3. Social network
4. Permanent membership of the mass movement</td><td rowspan="2">Customer segments
1. Students and teen agers
2. Corporate and professionals
3. Kids, elderly people, house wives and entire family
4. Any and all the segments of the society</td></tr>
<tr><td>Key Resources
1. land
2. plant-nursery
3. craftsmen
4. farmers and workers</td><td>Channels
1. Through social network
2. Awareness modules
3. Word to mouth</td></tr>
<tr><td colspan="3">Costs
1. Nursery, 2. crafts workshop, 3. land, 4. staff, 5. construction of a monument</td><td colspan="2">Revenue streams
1. Plant selling, 2. maintenance, 3. stone carving</td></tr>
</table>

Table 3 Business model canvas II

<table>
<tr><td rowspan="2">Key partners
1. Social network website
2. Online shop portal</td><td>Key activities
1. Social network website
2. Online shop portal</td><td rowspan="2" colspan="2">Value preposition
1. Remain connected with people with similar passion
2. Track your plant grow
3. Purchase exotic plants online
4. Purchase fresh organic vegetables and products</td><td>Customer relations
1. Help desk
2. Online support
3. Social Network
4. Permanent membership of the mass movement</td><td rowspan="2">Customer segments
1. Students and teen agers
2. Corporate and professionals
3. Kids, elderly people, House wives and entire family
4. Any and all the segments of the society</td></tr>
<tr><td>Key resources
1. Official website
2. Server and IT setup
3. Software engineers
4. Farmers and workers
5. Packing workshop
6. Supply chain network</td><td>Channels
1. Through social network
2. Awareness modules
3. Word to mouth</td></tr>
<tr><td colspan="3">Costs
1. Web site, 2. Transportation and logistics facility, 3. Skilled staff and workers, 4. Packing workshop for online sale</td><td colspan="3">Revenue streams
1. Online nursery and organic products store</td></tr>
</table>

Business Model canvas II:

The second canvas is about the online portal of the organic products and sapling store for the people. At the same time it also explains the social network website, on which the entire business model is interacting with customer base. The website is the back bone of the entire business model since it play major role in advertisement and attracting more and more people to the main vision and mission (Tables 2 and 3).

7 Conclusion

The business model is low cost sustainable model and can provide seasonal employment to the farmers. This business model will help in retaining the agricultural workforce in their native places at the same time can generate additional income for

them. It will help in generating social awareness regarding environment and help in achieving sustainability goals by spreading green belts. In the primary survey it was also asked from 150 daily wage workers that what if they get job opportunities at their home town with lower wages? 77% of workers proposed to stay at their native place with lower wages, since the cost of living in cities are very high and the savings are less. Hence they can save more in their native places with lower wages as compared to urban setup. Hence this business model will be helpful for both urban as well as rural population in catering in their desired needs.

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Workload Assessment Methods on Train Station Control Room

Madhura Vaidya and Anupam Tiwari

Abstract Workers at the train station control room undergo a tremendous mental workload. The job demands multitasking which can put a lot of strain on the staff. Mental as well as the physical workload on workers in such scenarios can be calculated using Nasa TLX (Task Load Index) is a broadly used, intuitive, multifaceted assessment tool that rates the perceived amount of effort so as to assess a function, organization, or unit's efficacy or other facets of attainment or using SWAT (Subjective Workload Assessment Techniques), a workload assessment method that asks subjects to rate the workload of a task based on the size of the time exposure, the exposure to mental exertion, and the exposure to psychological stress. Cognitive based ergonomic solution will be also given to reduce the mental workload will thus enhance productivity, improve efficiency and reduce errors. Finally, through Nasa TLX it was found that workers face high mental workload and through SWAT it was known that the workers undergo a high time load.

Keywords NASA TLX · SWAT · Train station control room · Productivity · Mental workload

1 Introduction

The NASA Task Load Index uses six measurements to survey mental responsibility: mental interest, actual interest, transient interest, execution, exertion, and dissatisfaction. The particular source of mental work created by different tasks is a vital determinant of workload experience. The three subscales are related to the subject's needs (intellectual, bodily, and time requirements), while the other subscales specialise in the interaction between the topic and the subject tasks (performance, endeavour,

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and frustration) [1]. SWAT is also a multidimensional scale, but it measures time exposure, mental effort, and psychological exposure at three different levels [2]. Studies have shown that, compared with other subjective workload assessments (for example, SWAT), NASA's TLX is the most popular among test subjects [3]. The objective of using these methods is to see the workload on the people working in train station control rooms in specific conditions.

A modern and reliable transport organization is a vital remedy to today's economic, environmental and social problems. With the increase in financing and the expansion of mass transit, newly developed train technologies have been established. Some developments are for execution, some are for interoperability, others are for trustworthiness, but eventually all for safety purpose. As the future public transportation industry shifts to higher-level transportation systems to improve safety, operator productivity and reliability become more and more important [4]. The workload is a term that refers to the cost of meeting the operator's task requirements. If people can do all the work they expect to be done rapidly, precisely, and reliably using existing means, then this idea will have no reasonable meaning. Because they are usually unable to do it, or because the labour costs (such as fatigue, stress, illness, and accidents) required to maintain performance are low [5].

2 Methodology

2.1 Nasa Tlx

Collection of data

A survey was taken from 31 members working in train control room stations using NASA TLX questionnaire method [6]. The train station control rooms are manned for 24 h a day through shifts. These are some of the working conditions of control room workers. The subjects have 3 shifts of 8 h from 7:00–15:00 h, 15:00–23:00 h, 23:00–7:00 h. The work is multi-tasking. All different kinds of departments work under the train station control room. It has different types of controllers such as follows: traffic, signal, EMU (Electric Multiple Unit), power, goods, garage, pathway, TPC (Traction Power Controller), RPF (Railway Protection Force), Commercial, etc. All workers under these controllers work coherently. The work is manual as well as digital. All subjects were approximate to the same working conditions. The workers are grouped age wise as shown in Table 1.

Table 1 Shows details of workers

Number of people	Age group
9	20–30
5	30–40
17	40+

The answers to the collected questions were analysed using NASA TLX worksheet (e.g., Fig. 1).

2.2 SWAT (Subjective Workload Analysis Technique) Analysis (Alternate Method)

Collection of data

A survey was taken from 31 members working in a train station control room using a SWAT questionnaire (e.g., Fig. 2).

3 Results and Discussions

3.1 NASA TLX Load Index

According to the overall analysis, it was found that 28 out of 31 (90.32%) face a high mental workload. While 29 out of 31 (93.54%) were successful in accomplishing the task they were given. Meanwhile, 22 out of 31 (70.96%) needed moderate physical activity during their work. 28 out of 31 (90.32%) feel high temporal demand. While 25 out of 31 (80.64%) need to take high efforts to accomplish the task. 28 out of 31 (90.32%) feel frustrated while working (See Fig. 3). The majority of people facing a high mental workload were from the age group 40+. Age group 20–30 felt more frustrated. The 40+ age group has more experience in the respective fields while lower age groups are new to the working environment. Therefore, the work for higher age group is moderately challenging and monotonous as compared to lower age groups. Sometimes due to other working conditions like emergency cases (engine failure, accidents on rail tracks) mental workload is increased. That time workload may differ.

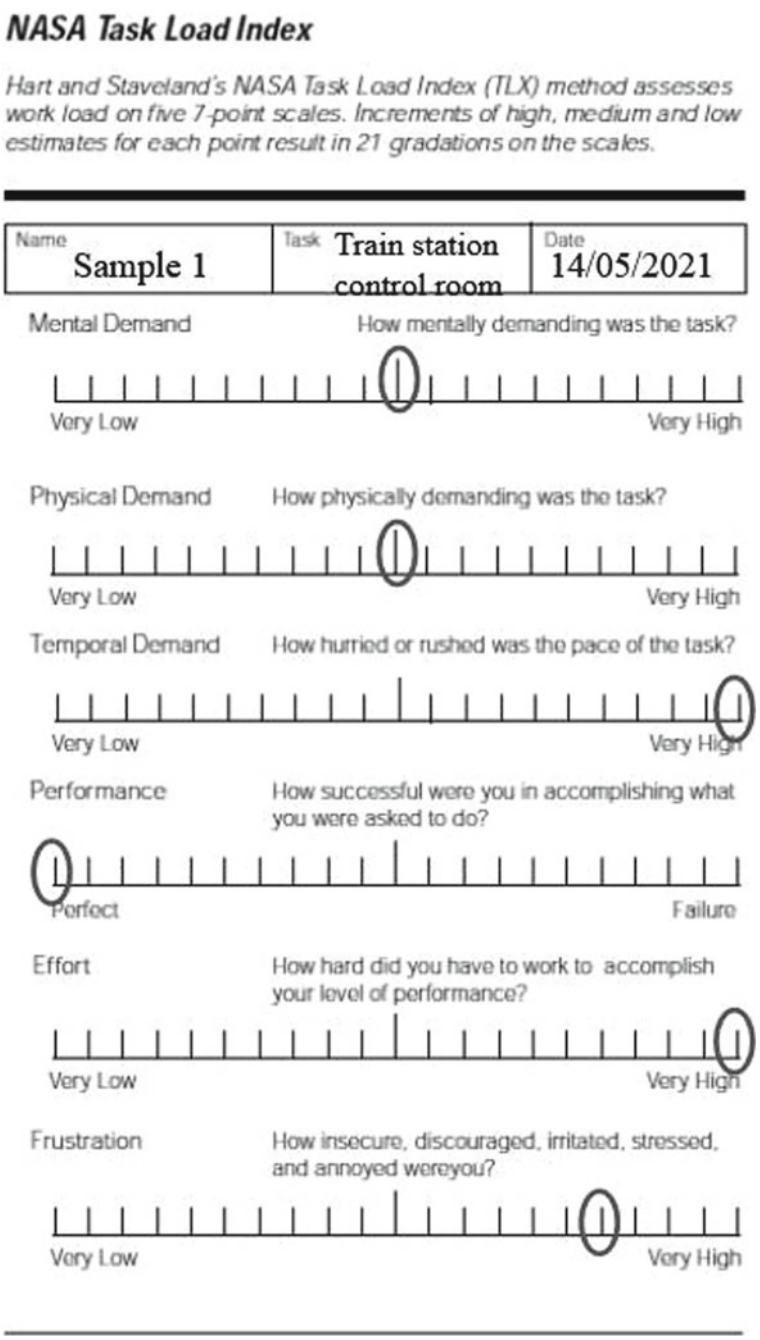


Fig. 1 Shows the analysis on one of the respondents of the train control room station

I. Time Load

1. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
2. Occasionally have spare time. Interruptions or overlap among activities occur infrequently.
3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

II. Mental Effort Load

1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
2. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainly, unpredictability, or unfamiliarity. Considerable attention required.
3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

III. Psychological Stress Load

1. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
2. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
3. High to very intense stress due to confusion, frustration, or anxiety. High extreme determination and self-control required.

Fig. 2 Shows a sample response from one of the respondents [7]

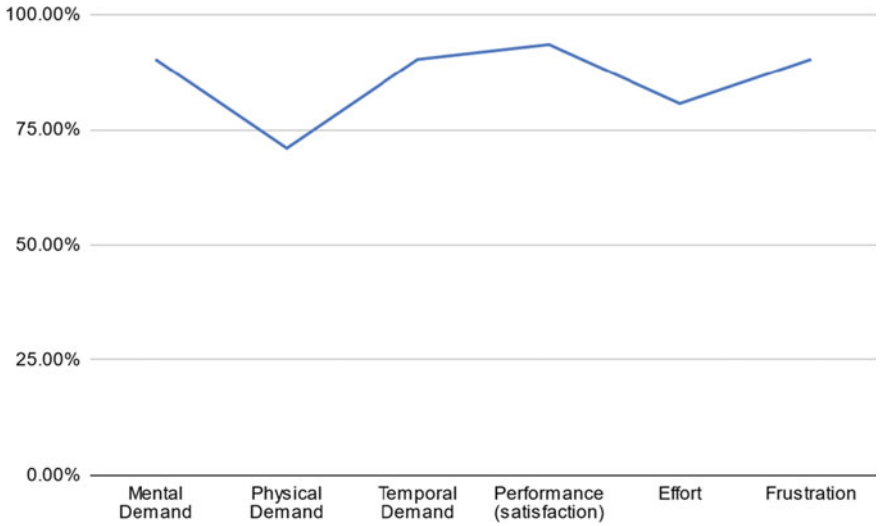


Fig. 3 Shows the overall analysis based on NASA TLX load index of 31 workers

3.2 SWAT (Subjective Workload Analysis Technique) Analysis (Alternate Method)

According to the overall analysis, it was found that 25 out of 31 (80.64%) members feel high time load. While 23 out of 31 (74.19%) members require moderate mental effort. 21 out of 31 (67.74%) members reported to have moderate psychological stress during work. The 40+ age group suffers more from time burden, mental strain and psychological worries since they have more responsibilities.

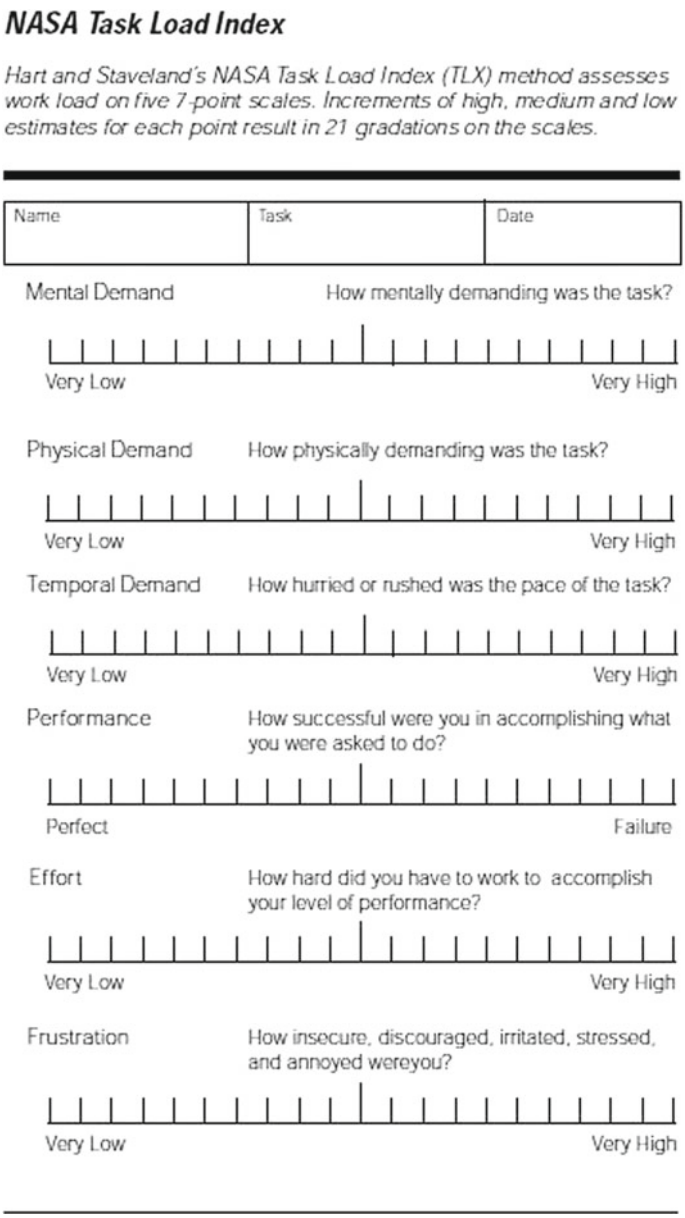
4 Conclusion

NASA TLX and SWAT analysis were performed by circulating the questionnaire through google forms. From the NASA TLX load index, it was found out that 90.32% suffered through the mental workload, frustration, and temporal demand. While in SWAT analysis 80.64% of members felt a high time load i.e. they don't get enough free time to relax. As we saw earlier, due to other working conditions these workloads may vary so to avoid such high levels of workloads following measures can be taken to reduce the stress, frustration and enhance the work experience and leading results.

1. User-friendly workspace design should be implemented so the productivity is boosted at the same time reducing the frustration [8].
2. The layout of data technology systems that aids psychological features to reduce catastrophic errors.
3. Frequent short breaks or more working shifts to be added for relaxation of both body and mind.
4. Executing a programmed rail track exchanging framework with mechanized control can give security to guarantee the accommodation of rail line innovation [9].
5. The chairs and the workspace can be ergonomically design to avoid MSD (Musculoskeletal disorders) risks. Frequent health check-ups of workers could also be provided.
6. Wireless sensor network (WSN) can be implemented to detect any prior threats instead of wired sensors. WSN boosts security and can work excellently in harsh climatic conditions. Wired technique needs more maintenance. WSNs can reduce the workload of the workers [10].

Appendix

NASA TLX Rating scale and definition. Source—https://en.wikipedia.org/wiki/NASA-TLX#/media/File:NasaTLX.png



NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?
Very Low — Very High

Physical Demand — How physically demanding was the task?
Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?
Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?
Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?
Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?
Very Low — Very High

SWAT (Subjective Workload Assessment Techniques) Scales

I. Time Load
1. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
2. Occasionally have spare time. Interruptions or overlap among activities occur infrequently.
3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.
II. Mental Effort Load
1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
2. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainly, unpredictability, or unfamiliarity. Considerable attention required.
3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.
III. Psychological Stress Load
1. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
2. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
3. High to very intense stress due to confusion, frustration, or anxiety. High extreme determination and self-control required.

NASA TLX questions circulated through google forms

1. age group
a. 20-30
b. 30-40
c. 40+

2. how much mental & perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking searching, etc)?
a. Low (0-7)
b. Average (7)
c. High (7-21)

3. Is the task easy or demanding?
a. easy & simple
b. complex & demanding

Nasa TLX form

4. How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)?
a. Low (0-7)
b. Average (7)
c. High (7-21)

5. How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
a. slow & leisurely
b. rapid and frantic

6. How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)?
a. Failure (Poor)
b. Perfect (good)

7. How hard did you have to work (mentally and physically) to accomplish your level of performance
a. Low (0-7)
b. Average (7)
c. High (7-21)

Nasa TLX form

SWAT questions circulated through google forms

1. how can you describe your time load at work?
a. Often have spare time. Interruptions or overlap among activities occur infrequently
b. Occasionally have spare time. Interruptions or overlap among activities occur frequently
c. Almost never have spare time. Interruptions or overlap among activities are very frequent.

2. how much mental effort is required at your work?
a. Very little conscious mental effort or very little conscious mental effort or automatic, requiring little or no attention.
b. Moderate or Conscious mental effort or concentration required. Complexity of activity is moderately high.
c. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

3. How much psychological stress load you feel at work?
a. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
b. . Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
c. High to very intense stress due to confusion, frustration, or anxiety. High to extreme frustration, or anxiety. High to extreme determination and self-control required

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Cognitive Status of Adult Bengalee Males Undergoing Training in Football

Satabdi Bhattacharjee, Tanaya Santra, Ayan Chatterjee, Surjani Chatterjee, Neepa Banerjee, Sandipan Chatterjee, and Shankarashis Mukherjee

Abstract Football, one of the most widely played body contact team game in the world, requires rapid motion, explosive running and jumping and other activities. In this context, a study has been undertaken on 33 randomly selected adult Bengalee males (aged between 18 and 24 years) receiving training in football constituting the Football Practicing Group (FG). BMI was found out. To assess lower level cognitive ability and cognitive flexibility trail making test (TMT) was conducted. Meta cognition of the participants was measured using D-KEFS Design Fluency Task (DFT). Similar tests were carried out on 36 individuals of comparable age, socioeconomic-ethnic status without formal training in any sports formed control group (CG). It may be observed, FG males have significantly ($P < 0.05$) better cognitive status in terms of higher and lower level cognitive functions than their age matched CG males.

Keywords Flexibility · Fitness · Mental stability · Sports performance · Mental skill

1 Introduction

Previous studies reported that apart from the physical, physiological, technical skills and basic coordination, psychological aspect of a sport has a significant potential to improve performance through mental training [1, 2]. It is observed that success in body contact sports based on information processing capability and the ability to react to a dynamic environment in a game condition. Not only the Physical competence, coordination also alone cannot envisage success in team sports and football is not an

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exception in that manner. Match analysis has revealed that the game is a mixture of aerobic and anaerobic endurance and the intensity of the game reaches from 80 to 90% of maximal heart rate (HRmax) [3]. In Football, many decisions must be made in fast and rapidly changing situations. The proficiency to generate skillful tactical movement and decision making with efficiency in a game condition is the most challenging part in football and the success of the game is actually hidden behind it. The necessary components of an innovative decision-making include both the accuracy and speed; that behavior helps the footballers to "read the game". Team game always demands coordination, speed, anticipation, motor skills, and memorizing ability [4]. The game intelligence is actually dealt with psychology and better to known as Executive Functioning (EF). Studies revealed that executive functions (EF) have essential significance in team sports like football [5–7]. Executive function (EF) is recognized as a process that can control over the thinking ability and action of an individual [8]. EF develops gradually through years and it has a proportional relationship between ages. Studies reported that cognitive processes usually mature through late childhood and it becomes highly mature at around 19 years of age [9–13]. In this backdrop, a study has been carried out on randomly selected adult Bengalee males receiving regularly training in football and to make a comparative study between similar age and socioeconomic-ethnic background matched individuals do not undergoing proper training in any types of exercises including football.

2 Methodology

Initially various institutes in and around Kolkata Metropolitan, providing training in football to adult male individuals contacted for receiving access to individuals for the study. The prerequisites of the study communicated. The measurements were taken in the morning hours on dates which were settled as per mutual convenience. 33 randomly selected male individuals (aged between18 and 24 years) with minimum experience of 6 years, practicing it for about a period of two hours every six days a week and with no chronic disease history (self- reported) were included in the present study and formed the Football Practicing Group (FG). Initially basic information was collected in the pre-designed schedule. Resting heart rate and blood pressure were recorded in the sitting position after a rest period of about 15 min [14]. Stature (m) was measured using stadiometer and body weight (kg) was measured using pre-calibrated weighing scale and subsequently BMI (kg m^{-2}) was calculated [15]. Percentage body fat % was calculated [16]. To estimate Reaction time (RT) of the study participants ruler drop method (RDM) [17] was carried out. The cognitive ability and cognitive flexibility of the study participants were assessed using trail making test (TMT) [18] and verbal fluency test [19]. Meta cognition of the study participants was assessed using D-KEFS Design Fluency Task (DFT) [20]. Similar Measurements were taken from 36 males of similar age, and socioeconomic-ethnic status without any types of training including football, formed the control group (CG). After obtaining the

measurements, data were subjected to statistical analyses using suitable statistical packages and significance level was set at $P < 0.05$.

3 Results

The basic physiological and physical characteristics features FG and CG individuals have been presented in Table 1.

Body composition of FG and CG individuals has been estimated by Body Weight (kg), Body Fat % and BMI (kg m^{-2}). In Figs. 1a, b Body Weight (kg) and Body Fat% of the study participants is presented.

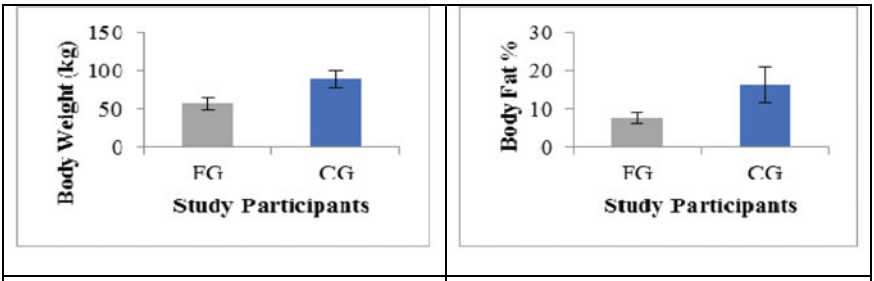
BMI, one of the most important, cheap, inexpensive and reliable parameters and has been used as a potent indicator of assessing obesity for so many years and it has been determined for FG and CG and presented in Fig. 2.

To estimate Reaction time (RT) of the study participants, ruler drop method (RDM) requiring materials like a standard ruler, pen and paper, minimal assistance, easy to administer, and has a moderate to good reliability and validity, was carried out. In Fig. 3 Reaction Time Score of the study participants has been presented.

Table 1 Basic physiological and physical profiles of FG and CG

Variables	FG	CG
Age (years)^	20.9 ± 1.89	21.1 ± 2.33
Stature (m)^	1.62 ± 6.02	1.61 ± 4.77
Body Weight (kg)*	56.4 ± 7.70	89.1 ± 11.54
SBP (mm Hg)^	114.8 ± 10.43	115.0 ± 6.80
DBP (mm Hg)*	64.7 ± 8.39	86.3 ± 5.60

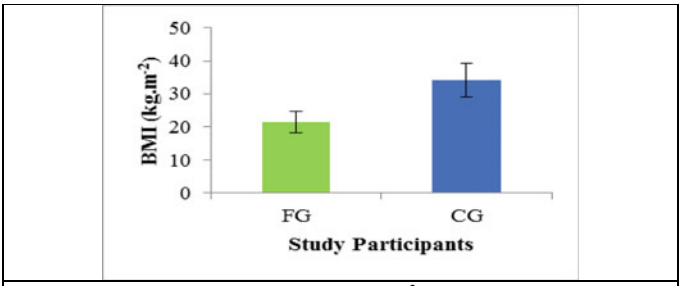
AM ± SD, *P < 0.05, ^ns



a Body Weight* | b Body Fat%*

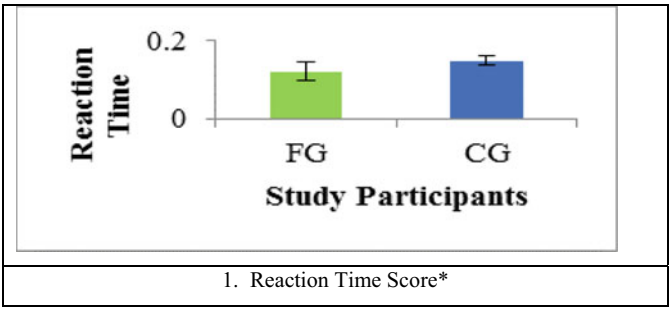
AM±SD, *P<0.05

Fig. 1 Body weight (kg) and body fat% of FG and CG: compared



AM±SD, *P<0.05

Fig. 2 BMI of FG and CG: compared



AM±SD, *P<0.05

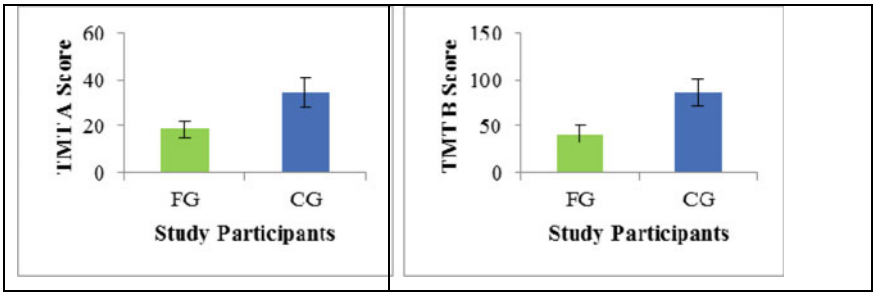
Fig. 3 Reaction time of FG and CG: compared

Cognition is one of the important aspects that play an important role in football. Different tests including Trail Making Test (TMT), Design Fluency (DF) test and Verbal Fluency test (VFT) have been carried out to assess the higher and lower level cognitive functions of the study participants. The cognitive ability and cognitive flexibility of the study participants have been assessed using Trail Making Test (TMT) and Verbal Fluency Test. In Fig. 4a, b Trail Making Test Scores of the study participants have been presented (Fig. 4).

The D-KEFS Design Fluency (DF) test is a testing protocol having the potential to estimates the Meta cognitive status. In Fig. 6a–c Design Fluency Test Scores of the study participants have been presented.

4 Discussion

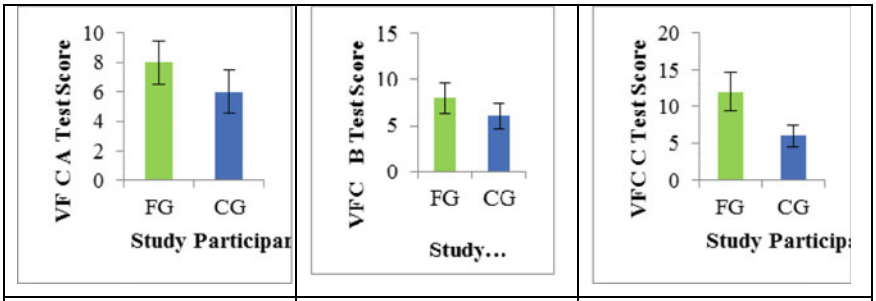
The research work was carried out to study the Cognitive Status of Adult Bengalee Male Individuals receiving training in football with the individuals of similar age,



a TMT A Test Score* | b TMT B Test Score*

AM±SD, *P<0.05

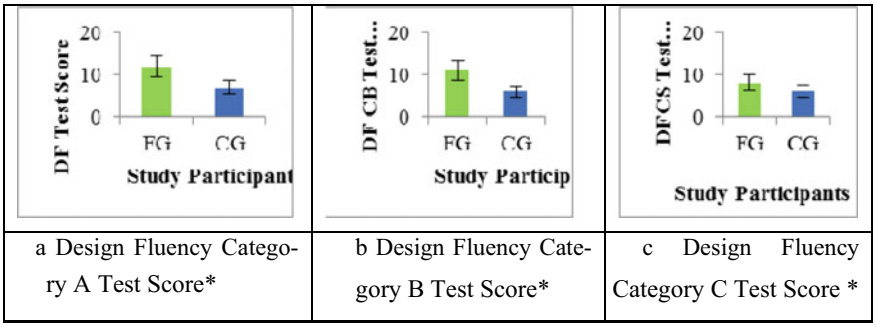
Fig. 4 Trail making test comprising TMT A and TMT b Test Score of FG and CG: compared



a Verbal Fluency Category A Test Score* | b Verbal Fluency Category B Test Score* | c Verbal Fluency Category C Test Score*

AM±SD, *P<0.05

Fig. 5 Verbal fluency test comprising verbal fluency category A, B and C Test Scores of FG and CG: compared



a Design Fluency Category A Test Score* | b Design Fluency Category B Test Score* | c Design Fluency Category C Test Score *

AM±SD, *P<0.05

Fig. 6 Design Fluency (DF) test comprising Design Fluency category A, B and C Test Scores of FG and CG: compared

and socioeconomic-ethnic status, and not receiving training in football and other such activities. To study the body composition status, parameters including stature, body weight, body fat (%) and BMI were selected. It this study, no significant ($P < 0.05$) difference is found in between FG and CG males in case of their Age (years), Stature (m) and Systolic Blood Pressure (SBP) (mm Hg) (Table 1) but they did vary significantly in Body Weight (kg) (Fig. 1a) and Diastolic Blood Pressure (DBP) (mmHg) (Table 1). Body Fat (%) and BMI (kg m^{-2}) of the FG and CG males has been determined. Body fat % is a relatively better and widely used well established body composition assessing parameter. It has been found in different epidemiological studies that accurate determination of body fat % could be helpful in assessing different metabolic disorders including high blood pressure, obesity, dysglycemia, dyslipidemia, and subsequent risk of metabolic syndrome (MetS), cardiovascular disease (CVD). In the present study, the FG individuals have significantly ($P < 0.05$) lower body fat % in comparison to their CG counterpart (Fig. 1b). The result may be due to the fact that football is considered as an intermittent short term collision sporting activity requiring high intensity pattern of activity and these activities have the potential to provide promising result in lowering adiposity especially abdominal adiposity. The present finding is in consonance with our earlier works conducted on adolescent and adult Bengalee male individuals receiving regular training in football and cricket [21–24] and in adult Bengalee females undergoing training in Indian traditional dance forms [25–29]. BMI (expressed in kg m^{-2}) is a useful parameter [30] and it has been found that the mean BMI (kg m^{-2}) values of FG males is significantly ($P < 0.05$) lower than their CG counterpart (Fig. 2) indicating CG individuals may have chances to develop physical and psychological health abnormalities that could hamper their regular activities. The present finding is in consonance with our previous works conducted on adult and adolescent football players [31–36] and in adult Bengalee females undergoing training in Indian traditional dance forms [37, 38]. Football is recognized as an open skill technical and tactical team sports where players need to react and move in an extremely changing, random and outwardly speedy environment. The cognitive status of the study participants has been assessed by using Ruler-drop Method, Trail Making Test (TMT), Verbal Fluency (VF) test and Design Fluency (DF) test. Reaction Time is generally estimating the ability of an individual to react to a stimulus or an object as quickly as possible and it has been estimated by using Ruler Drop Method (RDM). From the result it has been observed that the average Reaction Time Score (Fig. 3) is significantly ($P < 0.05$) lower in FG males in comparison to the CG males, indicating better Proprioception (body's sense of position and motion), important to get the information of the ball with the action of the opponent in a fast and quickly changing gaming situation. On the other hand, cognitive ability and cognitive flexibility of FG and CG males have been assessed by Trail Making Test (TMT) and Verbal Fluency Test. TMT a testing parameter, is important for assessing number sequencing, visual scanning, letter pattern, and also motor speed [2] of an individual. Moreover, lower TMT Score i.e., taken less time to complete the task, indicated better cognitive ability and cognitive flexibility of an individual. In the present study, the average TMT Score (including TMT A Score and TMT B Score) (Fig. 4a, b) of the FG males is significantly ($P < 0.05$) lower in

comparison with CG, indicating their better cognitive ability and cognitive flexibility. In additionally, verbal fluency test is having the ability to anticipate future events in terms of excellent planning, sequencing, selective and sustained attention, problem solving capacity, multi-tasking, and the capability to covenant with originality [39, 40]. It has been found that Verbal Fluency Test Score in terms of Phonemic fluency i.e., VFC A Test Score (Fig. 5a), Semantic fluency i.e., VFC B Test Score (Fig. 5b), and Clustering and switching. i.e., VFC C Test Score (Fig. 5c) of FG males is significantly ($P < 0.05$) higher than CG males. Cognitive flexibility in terms of planning, in generation of visual patterns, motor speed are the components of meta cognition and in the present study it has been estimated using D-KEFS Design Fluency (DF) test. It has been found from the result that, the average Design Fluency Test Score of the Football Practicing Group males is significantly ($P < 0.05$) higher than CG males, indicating better meta cognitive status in terms of readily anticipate and act in a quickly changing gaming conditions that happens frequently in a football match and this finding is in consonance with the earlier study carried on soccer and volley ball players [41].

5 Conclusion

It may be concluded that FG males have significantly better cognitive status in terms of both higher and lower level cognitive functioning compared to their age matched CG males.

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Analysis of Body-Gestures Elucidated Through Elicitation Study for Natural Locomotion in Virtual Reality

Priya Ganapathi and Keyur Sorathia

Abstract Proxy gestures are a powerful input interaction method for travel in virtual environments (VEs). Gestures provide an alternative mode of interaction for a design that is more natural and intuitive than the controller-based methods. A key challenge lies in understanding the patterns in the gestures and the relevant user behavior while performing the gestures in a specific scenario. In this paper, we classify and analyze the full-body travel gestures that were obtained as a result of our previous elicitation study. The travel gestures were performed in a seated position by 40 participants for 3 different VEs (VE1, VE2 and VE3) where the task of virtual travel was combined with placement task. We observed a total of 405 gestures and identified 24, 24, and 9 unique full-body gestures for the three different VEs respectively. We categorize them into upper body and lower body gestures. We further classified them based on hand usage and gesture form. The results indicate that *static pose and path* form was predominantly used in VE1 and VE3, *static pose* and *static pose and path* form was used in VE2. The findings also indicate that as the multitasking level increased in the VE, the usage of *dynamic pose* and *dynamic pose and path* form decreased. From the analysis, we obtain a better understanding of users' thoughts and behavior while performing the gesture. Using our results future designers and developers can identify suitable gesture categories for task-related to virtual travel in a seated position for multitasking scenarios.

Keywords Virtual reality · Locomotion · Virtual travel · Gesture classification · Body gestures · Gesture elicitation study

1 Introduction

Virtual Reality (VR) has gained immense popularity with the advent of low-cost headsets (i.e. Google Cardboard and similar) and sensing devices such as Microsoft's Kinect and Leap Motion. VR applications require the end-user to interact with the

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Virtual Environment (VE) and often demand virtual travel [1]. Natural locomotion provides the user with better proprioceptive and vestibular cues, thereby increases the sense of immersion [2]. However, in most VEs, real walking may not be a feasible option due to the limited tracking area, issues of physical fatigue, and safety concerns [3]. As an alternative, proxy gestures are interaction techniques that enable users to move within the VE [4]. This is achieved by performing body movements that serve as a proxy for walking while remaining stationary in the real world. Experiencing a large VE using standing-based proxy gestures induces more physical strain and fatigue to the user [3]. Moreover, these methods would be difficult to be used by the elderly and disabled users for travel in VR. Hence to mitigate the physical strain due to prolonged standing we explore travel techniques in a seated posture.

User-defined gestures are easier to learn and remember than the pre-defined gestures by system developers [5]. These gestures are found to be more natural and intuitive. We performed a gesture elicitation study, to obtain gestures for travel in a seated posture in three different multitasking VEs [6]. The task of virtual travel was combined with (i) VE1—both hands-free (ii) VE2—one hand occupied with placement task and (iii) VE3—two hands occupied with placement task. We obtained 405 gestures with 24, 24, and 9 unique gestures for VE1, VE2, and VE3 respectively.

In this paper, we categorize these unique gestures based on the upper body and lower body gestures. We further classify the gestures based on their geometric features such as hand usage and gesture forms. In observing and analyzing these user-defined gestures, we have gained insight into the mental models of the end-users. This helped us in finding the user behavior and gesture pattern for the virtual travel in three different VEs. Using our results designers can adopt the proposed gesture categories and further build upon the gestures to suit virtual travel tasks with one hand and two hands occupied.

2 Related Work

2.1 Gesture Elicitation and Classification

Many gesture classification schemes have been proposed over the years that involve speech-related hand movements [7, 8]. One of the earliest studies concluded that gestural behavior was conditioned by socio-psychological factors [7]. It resulted in five categories of gesture type which were physiographics, kinetographics, ideographics, deictic, and batons that formed the basis for other taxonomies. Another study classified gestures into iconic gestures (combining physiographics and kinetographics), metaphoric, deictic, and beats [8]. Both these studies classified the gestures augmented with human speech hence they can be applied only for certain interaction interfaces. Based on the linguistic properties gestures were classified into gesticulation, iconic, pantomimes, deictic, and symbolic [9]. A taxonomy of gesture types was established that was especially tailored for HCI called ‘gesture styles’ [10]. This was

further modified which lead to multiple and different gestures for the same action rather than a uniform set of gestures [11].

A gesture elicitation study was performed to obtain gestures for manipulation and navigation tasks for the tabletop interface. The obtained gestures were further classified along four dimensions such as form, nature, binding, and flow [12]. Another study explored the use of hand gestures for performing animation tasks in VR. They further analyzed the gestural interactions by classifying along semantic and geometric dimensions to identify the common trends in how participants expressed various spatial temporal operations [13]. A participatory design method was used to explore hand gestures in AR for 40 selected tasks [14]. The gestures were further classified based on the classification proposed in [12] to obtain a better understanding of the users' thoughts and behavior.

In our previous study, we conducted a gesture elicitation study for obtaining gestures for virtual travel task for different multitasking environments [6]. In present paper, we analyze the unique gestures obtained based on their geometric dimensions. Many studies have analyzed and classified gestures in different contexts; however, studies performing elicitation and classification of full-body gesture for virtual travel in varied conditions are not presented, to the best of our knowledge.

2.2 Geometric Taxonomy of Gestures

We classified gestures along with taxonomies based on hand usage [15] and form [12] (Table 1).

Hand Usage: Hand usage distinguishes between unimanual and bimanual gestures [12]. Unimanual gestures in navigation correspond to gestures that ensure that the user can fully control his or her position in a virtual space using a single hand. This leaves the second hand to be free for other tasks. Bimanual gestures allow the user to navigate by performing the gesture with both hands at the same time.

Gesture Form: Form categorizes if and how the pose and position of the hand vary within a gesture. Table 1 briefly describes and Fig. 1 illustrates the four categories [12, 13]. Examples concerning hand include using a closed fist—*static pose* (Fig. 1a); tracing out a path—*static pose and path* (Fig. 1b); pinch and release—*dynamic*

Table 1 Hand usage and gesture form

Hand usage	Unimanual	Only one hand is used to specify the gesture
	Bimanual	Both hands are used symmetrically to specify the gesture
Form	Static pose	The pose is held in one location
	Static pose and path	The pose is held while it moves
	Dynamic pose	The pose changes at one location
	Dynamic pose and path	The pose changes as it moves

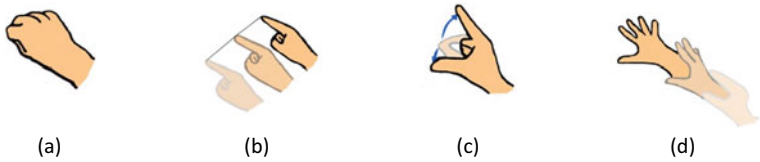

Fig. 1 Gesture form classification **a** Static pose, **b** Static pose and path, **c** Dynamic pose, **d** Dynamic pose and path. Picture adapted from [13]

pose (Fig. 1c), and throwing objects—*dynamic pose and path* (Fig. 1d). A bimanual gesture is considered to have a *dynamic pose and/or path* if either of the hands satisfies the respective criteria. We have extended the same knowledge in the present study to classify travel gestures in VR that involve upper and lower body parts.

3 An Overview of the Gesture Elicitation Study for Travel Gestures

3.1 Design of VEs

The VE used for the elicitation study consisted of a maze where participants traveled from location A (start of the maze) to location B (end of the maze) with a total distance of 200 m (Fig. 2a). The same VE was used for three different scenarios. In VE1, participants performed only virtual travel with both hands-free of any tasks. In VE2, participants performed virtual travel along with one of their hands occupied with the placement task. In VE3, participants performed virtual travel with both of their hands occupied with the placement task. Participants traveled each VE for 2 min. The placement task in VE2 (Fig. 2b) was to carry one object from location A and place it in location B with one hand. The placement task in VE3 (Fig. 2c) was to carry one object in left hand and another object in right hand simultaneously from

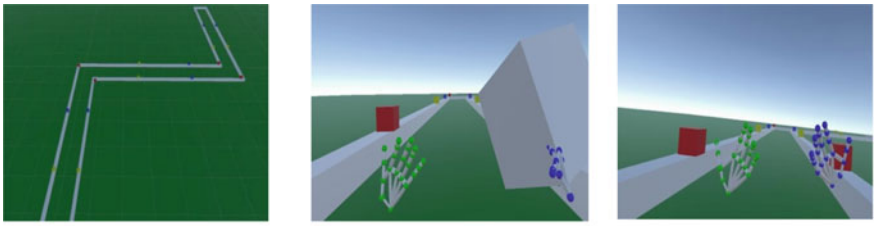

Fig. 2 **a** Path to be traveled in VE1, VE2, and VE3, **b** VE2 with one hand occupied, **c** VE3 with two hands occupied

location A and place them in location B. The selection and carrying of objects was performed using grab gesture.

3.2 Procedure

A group of 40 university students aged from 21 to 35 years participated in the study. They were given initial training for the placement task. The VEs presented during the training session were different than the VEs used in the experiment to eliminate route biases. The task performed was the virtual travel from position A to position B in a seated position. The participants were asked to perform at least 2 gestures that were natural, intuitive, and best represented the task for travel in the given VE. However, they were free to perform more gestures. While performing the gesture, participants were encouraged to think aloud and explain the gesture they were performing. Prior consents were taken from the participants for video recording the study.

3.3 Elucidated Gesture Overview

We obtained a total of 405 gestures with 155,141 and 109 gestures for VE1, VE2, and VE3, respectively. We analyzed the recorded user sessions to identify the most commonly observed gestures for our virtual travel tasks. To avoid redundancy, gestures that had the same shape and or trajectory were grouped into a single gesture. From the total gestures that were obtained, we found 24, 24, and 9 unique gestures for VE1, VE2, and VE3 respectively.

4 Results and Discussions

We used the verbal explanations, mental models, and thought processes of participants obtained from the think-aloud sessions to categorize the gestures. These sessions were video recorded. We further classified based on the pose and position of the body part performing the gestures as in Fig. 3. In this section, we discuss the set of unique gestures that were identified for the three different VEs and their classification based on the geometric taxonomy of gestures. In analyzing and classifying these user-defined gestures, we gain a better understanding of the gesture pattern, users' thoughts, and behavior while performing the travel task. Using our results interface designers can adopt the proposed gesture categories and further develop the gestures suitable for VE with hands-free travel, one hand-occupied travel, and two hands-occupied travel tasks.

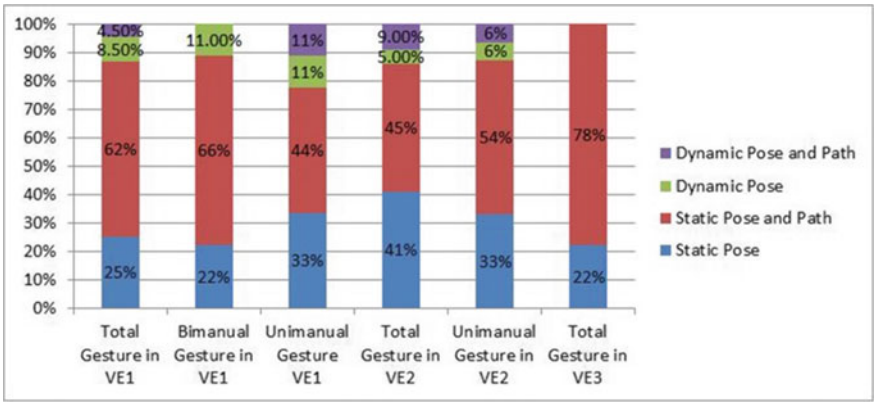

Fig. 3 Classification of unique gestures based on gesture forms in VE1, VE2, and VE3

4.1 VE1—Virtual Travel with Both Hands-Free

We identified 24 unique gestures for VE1 as shown in Table 2. In this scenario, both hands were available for participants to perform the gesture. The participants performed 19 upper body gestures (79%) and 5 lower body gestures (21%). A higher preference of upper body gestures was seen as people felt that performing upper body gestures were easier and convenient than performing lower body gestures in a sitting position. One participant stated that "*I would like to sit in VR to avoid fatigue and performing a lower body gesture would increase the physical strain*". In hand usage, 9 gestures were performed as bimanual and 9 gestures were performed as unimanual. Participants felt the bimanual gestures were faster and provided a greater sense of spatial awareness because of the symmetrical hand movement. Participants performed bimanual gestures such as *Arm-Swinging*, *Arm-Cycling,* and *Deictic Pointing with both hands alternatively.* These gestures allowed interaction while preserving the realism of walking that is natural to human gait. We observed that participants felt bimanual input for locomotion had greater control over the speed of movement, thereby achieving the desired balance and confidence similar to [16]. One participant stated that "*I feel like having greater control on the speed while moving if I use both the hands and it gives realistic virtual bipedal steps*".

We identified that from the total gestures *static pose* was observed 25%, *static pose and path* was 62%, the *dynamic pose* was 8.3% and *dynamic pose and path* was observed 4.1% of the times. Within the bimanual gestures *static pose* was observed 22%, *static pose and path* was 66% and *dynamic pose* was observed 11% of the times. In the unimanual gestures *static pose* was observed 33%, *static pose and path* was 44%, the *dynamic pose* was 11% and *dynamic pose and path* was observed 11% of the times.

Travel is a continuous activity to map the gestures to movement in the virtual world. Hence, we observed that participants performed more of *static pose and path*

Table 2 Classification of unique gestures of VE1 based on hand usage and gesture form

Sr. No	Gesture	Upper body	Lower body	Static pose	Static pose and path	Dynamic pose	Dynamic pose and path
1	Deictic pointing with one hand (unimanual)	x		x			
2	Deictic pointing with both the hands alternatively (bimanual)	x		x			
3	Deictic pointing at a reference point and teleporting to that point (unimanual)	x		x			
4	Bike-riding/closed fist of both hands (bimanual)	x		x			
5	Swimming/moving both hands in the opposite direction (bimanual)	x			x		
6	Arm—cycling (bimanual)	x			x		
7	Tapping with the palm facing down on the thigh (unimanual)	x			x		
8	Torso leaning	x			x		
9	Finger tapping on the thigh or arm-rest (unimanual)	x			x		
10	Cyclic movement of the hands as to calling someone (bimanual)	x			x		
11	One leg on heels and tapping		x		x		
12	Place one leg forward for walking		x	x			
13	Sliding the hand from left to right (unimanual)	x			x		

(continued)

Table 2 (continued)

Sr. No	Gesture	Upper body	Lower body	Static pose	Static pose and path	Dynamic pose	Dynamic pose and path
14	Open hands placed vertically moving up and down as in running (bimanual)	x			x		
15	Arm-swinging (bimanual)	x			x		
16	Pulling, grabbing, or pinching the environment towards the user (unimanual)	x				x	
17	Tapping with toes/heels on the ground—tap accelerator		x		x		
18	Walking-in-place (WIP)		x		x		
19	Wiping the legs		x		x		
20	Closed fist hands as if rotating steering in a car. (bimanual)	x			x		
21	Finger-walking in mid-air (unimanual)	x					x
22	Showing one finger to walk (unimanual)	x		x			
23	Zoom in and out using two fingers (bimanual)	x					x
24	Moving a closed fist as if pulling up a lever (unimanual)	x			x		

form of gesture in the elicitation study. The gestures corresponding to *static pose and path* had a natural correspondence with travel in the real world. For example, the *Arm-Swinging*, *Swimming*, *WIP*, *Tapping*, *Wiping* gesture map to real-world travel gestures. They involve motor body parts that are used in the walking gait cycle. One of the participants stated, "*The WIP gesture and Arm-Swinging gesture are very natural and intuitive as we use in our real-world walking activity*". The *Finger-Walking* gesture was found to impart better spatial knowledge to the participant similar to [17] but also produced physical fatigue in the fingers after some time. The gesture '*Pulling, Grabbing or Pinching the environment towards the user*' was found to be more tiring and was also prone to simulation sickness, similar to the

point-tugging method discussed in [18]. This might be the reason that the *dynamic pose* and *dynamic pose and path* form were used very rarely as they were difficult to perform for a continuous activity such as locomotion.

We observed that the participants adopted a vehicle metaphor while performing the tasks. Among the vehicle metaphor gestures, 50% of the gestures were in correlation to the *static pose and path* form. *Leaning*, *Tap-Accelerator*, *Car Driving* gestures were used to get the feel of moving in a vehicle. The *Bike-Riding* gesture required more effort as it did not have any tangible handle to rest the hands over. During the turns, *Bike-Riding* gestures and *Leaning* gestures were found to be very smooth and directly related to the movement of riding.

4.2 VE2—Virtual Travel with One Hand Occupied

We identified 24 unique gestures for VE2 as shown in Table 3. We observed 16 upper body gestures (67%) and 8 lower body gestures (33%). Upper body gestures were performed more than the lower body gestures similar to VE1 as participants were comfortable performing gestures with one hand. All the hand gestures performed in VE2 were unimanual.

We identified that from the total gestures *static pose* was observed 41%, *static pose and path* was 45%, the *dynamic pose* was 4.1% and *dynamic pose and path* was observed 8.2% of the times. Within the 15 unimanual gestures *static pose* was observed 33%, *static pose and path* was 54% and *dynamic pose* was 6.3% and *dynamic pose and path* was observed 6.3% of the times.

We observed that *static pose* and *static pose and path* form of gesture occurred the most in VE2. The gestures corresponding to these two forms have natural correspondence to the natural walking gait cycle such as *WIP*, *Arm-Swinging*, *Tapping*, *Wiping*, and *Swimming* gestures. Furthermore, the majority of the resulting gestures for *static pose* were simpler to recognize than *dynamic pose and path gestures*. This finding is similar to the results obtained from the study [14] in which user-defined hand gestures for augmented reality mostly were *static pose* or *static pose and path* as they were easily recognizable. Participants felt effortless while performing the *static pose* gestures such as a '*Closed-Fist*' or '*Showing a Finger for Walking*' though they were not very natural. "*When I show a single finger for travel it is explicit, very effortless, easy to perform*". The *Leaning* gesture which had the *static pose and path* was found to be more natural; felt more immersed and produced enhanced forward linear vection similar to the findings of [19]. *Dynamic pose* and *dynamic pose and path* form of gesture was rarely used because one hand was occupied in carrying an object. Hence, people preferred simple hand gestures for movement in VE. One of the participants stated, "*Performing Finger-Walking gesture in this environment is difficult because one hand constantly occupied with an object, and the other hand is used for travel task*". Similar to VE1, we observed participants had a strong correlation with the vehicle metaphor while traveling in VE2 also. Participants performed

Table 3 Classification of unique gestures of VE2 based on hand usage and gesture form

Sr. No	Gesture	Upper body	Lower body	Static pose	Static pose and path	Dynamic pose	Dynamic pose and path
1	Deictic pointing at a reference point and teleporting to that point	x		x			
2	Deictic pointing with one hand	x		x			
3	Closed fist and open arms	x		x			
4	Cyclic movement of one hand as to calling someone	x			x		
5	Tapping hand with the palm facing down on the thigh	x			x		
6	Raising one leg to walk		x	x			
7	Tapping with the palm facing down on the thigh	x			x		
8	Torso leaning	x			x		
9	Placing both the legs forward		x	x			
10	Arm-cycling with one hand	x			x		
11	Placing one foot forward		x	x			
12	Place one leg on heels for walking		x	x			
13	Show one finger for walking	x		x			
14	Sweeping/sliding one hand from right to left	x			x		
15	Swimming/moving one hand from center to side	x			x		
16	Open hand placed vertically and moving up and down as in running	x			x		

(continued)

Table 3 (continued)

Sr. No	Gesture	Upper body	Lower body	Static pose	Static pose and path	Dynamic pose	Dynamic pose and path
17	Pulling, grabbing, or pinching the environment towards the user	x				x	
18	Walking-in-place (WIP)		x		x		
19	Wiping the legs		x		x		
20	Arm-swinging with one hand	x			x		
21	Tapping with toes/heels on the ground—tap accelerator		x		x		
22	Finger-walking in mid-air	x					x
23	Closing fist	x		x			
24	Moving a closed fist as if pulling up a lever	x			x		

gestures such as '*Moving a closed fist as if pulling up a lever*' visualizing an aircraft or car travel.

4.3 VE3—Virtual Travel with Two Object Selection and Manipulation

We identified 9 unique gestures for VE3 as shown in Table 4. In this scenario, since both hands were occupied in carrying the object, the participants had the torso and lower body parts for performing the gesture for travel. We observed 3 upper body gestures (33%) and 6 lower body gestures (66%).

We found from the total gestures *static pose* was observed 22%, *static pose and path* was observed 78% of the times. There were no gestures related to *dynamic pose* and *dynamic pose and path* form.

We observed that participants performed gestures closely connected to real life, i.e. *WIP*, *Tapping,* and *Wiping*. They also used the vehicle metaphor gesture such as *Tap-Accelerator* gesture while performing travel similar to VE1 and VE2. Participants felt the WIP gesture as the most natural and intuitive gesture when both hands were occupied. It also utilized the transferability between leg and hand gestures since

Table 4 Classification of unique gestures of VE3 based on hand usage and gesture form

Sr. No	Gesture	Upper body	Lower body	Static pose	Static pose and path	Dynamic pose	Dynamic pose and path
1	Torso leaning	x			x		
2	Raising both the legs up for walking		x		x		
3	Place one leg forward for walking		x	x			
4	Place both the legs forward for walking		x	x			
5	Walking-in-place (WIP)		x		x		
6	Wiping the leg		x		x		
7	Tapping with toes/heels on the ground—tap accelerator		x		x		
8	Closed fist hand placed vertically and moving up and down as in running	x			x		
9	Arm-swinging	x			x		

both hands were occupied. Further, participants felt that the *Leaning* gesture could be an inclusive gesture that can be used for disabled users for virtual travel when the gestures cannot be performed by legs or hands. The other upper body gestures were *Arm-Swinging* and *Running* gesture. However, participants found it difficult to perform in a multitasking setup. Thus, similar to the findings of [20], when the multitasking level increased, participants proposed gestures that used *static pose* or *static pose and path* form gestures.

5 Conclusion

In this paper, we present the classification of the user-defined gestures for locomotion for three different VEs based on the upper body and lower body gestures. The findings suggested that for VE1 and VE2 people elucidated more upper body gesture than lower body gesture as they felt it more comfortable in a seated position. In VE3 lower body gestures were predominantly used as the level of multitasking increased with hands. We further classify the gestures based on their geometric taxonomy. It was observed that as the level of multitasking increased from VE1 to VE3 people

preferred gestures with *static pose* and *static pose and path* more than *dynamic pose* and *dynamic pose and path* gestures. We also observed that participants adopted vehicle metaphor while performing the tasks as they were traveling the VE in a seated position. *Static pose and path* form constituted 50% of the vehicle metaphor gesture. We found that *dynamic pose* and *dynamic pose and path* form gestures induced physical fatigue when used continuously for travel. Using our results future designers and developers can identify suitable gesture categories for task-related to virtual travel in a seated position for multitasking scenarios.

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Identification of Ergonomic Risk Factors in Dhokra Bell Metal Handicraft Industry of Chhattisgarh, India

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Abstract This paper presents an ergonomic assessment of risk factors involved with the bell metal handicraft processing industry of Chhattisgarh, India. Bell metal casting is one of the ancient traditional handicrafts practiced in India. In Chhattisgarh, Ghadwas tribe group were involved with this craftwork from ages and used the term "Dhokra". This craftwork is recognized worldwide for its unique style of metal sculpting and ornamentation process. For centuries this craftwork survived with many challenges, and the rich knowledge of craftsmanship was passed down from one generation to the next. In this survey 120 artisans participated, of which 60 were females and 60 were males. The survey was divided into two phases (1) Identification of the ergonomic risk factors in the existing workplace. (2) Prioritization of the risk factors. In the first phase, modified Nordic questionnaires, RULA, REBA and OWAS techniques were used to identify the problems in the existing workplace. In the second phase, the risk factors were prioritized by comparing data techniques to mitigate high ergonomic risk in the existing workplace with proper action plans. It revealed that artisans faced posture-related Musculoskeletal disorders (MSDs) during crafting activities. Through analysis and observation of the result it was concluded that artisan's health mostly affected by improper body posture, workload and unorganized nature of work. The crafting process forced to work in wrong posture, increasing overall discomfort and pain. Moreover, it suggested that ergonomics intervention in tool, work process and workstation design will be helpful to prevent MSDs.

Keywords Ergonomic risk assessment · Bell metal handicraft industry · RULA · REBA · OWAS · MSDs

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1 Introduction

From the Bronze Age (3000-1800BC), the lost wax process is practiced in India [1]. The beautiful doming girl image found from Mohenjo Daro is evidence of this craft [1]. In the world, only India has a beautiful and unbroken tradition of crafts [2]. Dhokra, a traditional tribal metal craftwork practiced in households predominately in Kondaga on District of Chhattisgarh. Ghad was tribal community peoples were associated with this craftwork [3]. Dhokra craft artisans have their own traditional technique of metal casting into different forms based on the availability of raw materials, environmental conditions and individual skills in dhokra craft. The main crafting process includes, wax ornament preparation, mould preparation, casting and polishing. Dhokra handicraft is a home-based manufacturing production process where hand tools, workstations used are age-long. High production demand due to the commercialization in this sector results the artisans to work for long duration in workstation not designed for commercial usage. In Handicraft sector, product value depends on quality production. Quality again depends on the efficiency of the artisan's. Ergonomic principles play an significant role in increasing the efficiency of the artisans. Dhokra craftwork is a highly precession task. The nature of production needs long duration of work. This represent ergonomic risks and the primary reasons behind injury to the artisans. Improper workstation forced the artisans to perform their activities in awkward posture. It was further discovered that employees who were subjective to repetitive task for an extended period of time develops very high rate of MSD. Work-related MSDs are triggered by a complex interplay of risk elements, including body posture while working, iterative & forceful movements and static muscle load [4].

Occupationally induced or exacerbated MSDs (Musculoskeletal disorders) is the most common health issue that negatively impacts the quality of life [5, 6]. Occupation related exposures involving extremely iterative & monotonous jobs that include gripping of the hands, localised mechanical pressure and repetitive wrist bending and vibration play a significant role in developing upper-limb MSDs [7, 8]. The lack of awareness about safety guidelines of the reason for the development of MSDs and health problems among artisans affect them economically in the long run [9–11].

Dhokra handicraft belongs to the unorganised sector. In this sector, men and women worked together to survive. Dhokra is part of their traditional culture. Artisans performed this precision-based task (Fig. 1) with static load, but they do not have a defined workstation. A similar precision-based activity was found in handloom, gota Patti and blue pottery handicraft, where the wrong posture was the primary concern [12]. Discomfort in different gender due to bad posture was also identified among the brickfield workers [13]. In footwear making activity, it observed that the entire process carried out in awkward postures, where the study found that new workstation design can reduce the high risk of MSDs [14]. Researcher also identified postural strain development due to poor posture in industrial workplace [15]. The connection between bad posture and pain/symptoms of MSDs has been documented in many studies [16–18]. Ghosh et al. [19] found that without proper ergonomic principles,

Fig. 1 Precisely sticking wax pieces on base surface by hand with awkward sitting posture

workers are forced to adjust themselves to bad working conditions in goldsmith work. When faced with high work demands, redesigning the work process with ergonomic interventions can address an individual's work posture and help reduce the MSDs risk and their extremity [20]. While designing tools, machines, equipment and workstations without applying ergonomics principles, the fact is neglected that people are of all different stature and have different strength levels. These distinctions must be taken into account for workers health as well as comfort.

There was no ergonomics study available on Dhokra handicraft. However, this traditional handicraft has its importance for their artisans. This skilled-based handicraft passed from one generation to another generation. Here need to be focused on artisans efficiency; as mentioned earlier in literature, the efficiency of workers is affected due to poor working posture. So the current study focused on; The crafting process of the existing workstation to identify the postural discomfort factors responsible for the development and prevalence of MSDs.

2 Methodology

2.1 Selection of Participants

Data were collected from 120 artisans involved in bell metal handicraft processing industry in the Kondaga on district of Chhattisgarh, India, between October 2020 and February 2021. Sampling was done by purposive and then random sampling method from different handicraft units. 60 female and 60 male artisans were selected from 15 handicraft units. Weight in Kg and height in cm was measured among all the artisans involved in the research to calculate Body mass index (BMI) [21].

2.2 *Postural Analysis and Body Discomfort Analysis*

The study of the various working postures involved was done with the help of the Rapid Entire Body Assessment (REBA) [13], Rapid upper limb assessment (RULA) [8] and the Ovako Working Posture Analysis System (OWAS) [22]. A modified Nordic questionnaire [23] was used, which has several questions focusing on each artisan details, MSD symptoms, affected body parts, etc. [24]. The Numerical Rating Scales [25] used a 5-point rating scale, where 1 indicated 'not uncomfortable/comfortable' and 5 'extremely uncomfortable'. Dhokra crafting process has divided into eight steps, which includes different type of crafting activities (Fig. 2). According to this, out of 120 artisans divided it in to eight groups of 15 artisans for each crafting steps. The body part discomfort (BPD) scale was used to measure the level of discomfort experienced by artisans in the different steps of manufacturing activities after 3 h of work. Then 45 min of interval took data 4 times from each group of artisans. "The scale can be administered at intervals throughout the working period, to measure discomfort over time" [4]. All statistic were performed in SPSS.

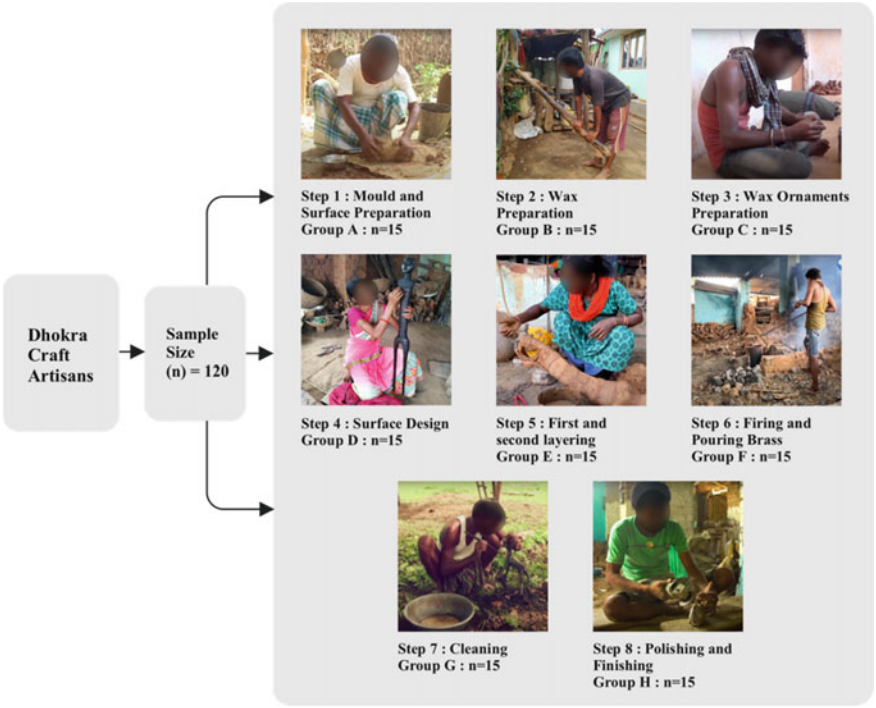


Fig. 2 Dhokra artisans involved in different steps of crafting process

3 Result

The mean value of weight, height, age and the work experience of the artisans is shown in Table 1. The artisans had average more than 15 years (16.53 ± 10.42) of work experience on average, from a minimum experience of 3 years to a maximum of 53 years. Table 1 also shows the routine task schedule with the average hours of task and the weekly working days. Observation indicates artisans work on average 6.03 ± 0.72 days in a week.

The repetitive nature of the activities, such as designing, mixing, hammering and polishing, was observed in the crafting activity. All these activities are continuously done without resting, where artisans spend an average of 6.73 ± 1.12 h per day. Due to these activities, the average body mass index value found to be 19.36 ± 2.76 kg/m^2 comes in the underweight region, where the minimum value was 13.5 kg/m^2.

The Dhokra crafting process was divided into eight steps (Fig. 2). In the first step, it required effort with both legs and hand in awkward posture. The second step, The mixture of wax dough converted into wax wires (strips) using an extruder device. In the third and fourth step, thin molten wax wires was used to make detailed designs/artefacts on the clay moulds. It requires precision work for maintaining the quality of each detailed design. In the fifth step, the two-layer of clay used to cover the wax design so that the clay acquires a detailed form from the wax model. This repetitive work require both hand efforts with an awkward sitting posture. In the Sixth casting step, two furnaces are used simultaneously. One furnace is used to prepare the mould, and the other is used to melt brass to pour it on the mould. During these activities, artisans handle heavy piece of the mould with exposed enough heat. After cooling, the clay moulds are broken using a small hammer to reveal the raw piece in the seventh step. The repetitive nature of the activities, such as designing, mixing, hammering and polishing, was observed in the crafting activity. All these activities are continuously done without resting, where artisans spend an average of 6.73 ± 1.12 h per day. Due to these activities, the average body mass index value found to be 19.36 ± 2.76 kg/m^2 comes in the underweight region, where the minimum value was 13.5 kg/m^2 . In the eighth step of buffing, the artefact is then given a polished

Table 1 Demographics of Dhokra artisans

Parameter	Min	Max	Standards deviation
Age (years)	17	76	34.82 (±13.13)
Height (cm)	131	192	158.37 (±11.32)
Weight (kg)	33	78	48.54 (±7.60)
BMI (kg/m^2)	13.5	29.9	19.36 (±2.76)
Working experience (years)	3	53	16.53 (±10.42)
Duration per day (h)	5	8	6.73 (±1.12)
Working days per week	5	7	6.03 (±0.72)

finish. All of these steps included different activities, which needs manual effort with repetitive action. Some activities were performed in awkward posture and forceful exertions with very little recovery time between movements.

The Dhokra handicraft activity was analysed with the help of RULA, REBA and OWAS for analysing postural load on the artisans and categorizing the possible harmfulness work posture in Table 2. The OWAS final score shows that postures in different crafting activities like step 1, 2, 3, 5, 6 and 8 require corrective measures. The RULA and REBA output results indicated that work should pause until a safer and better solution can found in crafting step 2, 3, 5 and 6.

Table 3 shows the discomfort in different body parts. In this study, Nordic data indicated that most of the discomfort feelings are in the upper arm (63.8%), forearm (67.7%) and hand (69.1%) on hand region reported by artisans. The artisans also reported pain in the buttocks (57.5%), lower leg (55.1%) and Knee (67.7%), affecting the lower limb region. The study of BPD data indicated most of the discomfort feeling with associated groups. Where In group D, artists who are involved in surface design activities, most of they feels discomfort in their upper limb region, neck (80%), Forearm (86.67%) and Hand (88%). In the casting activity group, F artisan has

Table 2 Analysis of work posture of Dhokra artisans

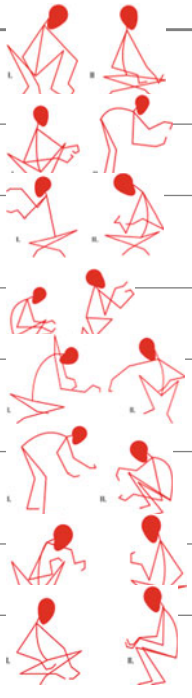
No of steps in Dhokra crafting activities		Posture		Posture analysis		
		I	II	RULA score	REBA score	OWAS score
1	Mould and surface preparation		I	6	7	4
			II	6	6	2
2	Wax preparation		I	3	7	2
			II	7	12	3
3	Wax ornaments preparation		I	7	11	2
			II	6	6	2
4	Surface design		I	4	7	2
			II	5	10	1
5	First and second layering		I	7	12	3
			II	4	6	2
6	Firing and pouring brass		I	7	12	3
			II	6	6	2
7	Cleaning		I	6	7	4
			II	3	6	2
8	Polishing and finishing		I	6	7	2
			II	4	6	2

Table 3 Nordic group and BPD group data for frequency of discomfort

Different body part discomfort		Nordic score (%)	BPD score (%)							
			Group A	Group B	Group C	Group D	Group E	Group F	Group G	Group H
		n = 120	n = 15	n = 15	n = 15	n = 15	n = 15	n = 15	n = 15	n = 15
Pain	Neck	47.7	46.67	21.33	78.67	80*	44	20	37.33	45.33
	Shoulder	41.1	29.33	38.67	46.67	49.33	21.33	56*	52	30.67
	Upper Arm	63.8	53.33	56	68	70.67	52	73.33	74.67*	62.67
	Forearm	67.7	61.33	49.33	80	86.67*	65.33	57.33	84	66.67
	Wrist	58.1	54.67	45.33	72*	69.33	62.67	24	69.33	66.67
	Elbow	58.1	45.33	34.67	65.33	61.33	54.67	65.33	72*	61.33
	Hand	69.1	69.33	58.67	85.33	88*	72	50.67	81.33	44
Pain	Lumber	48.8	49.33	54.67	48	41.33	46.67	62.67*	45.33	32
	buttocks	57.5	64	57.33	69.33*	65.33	61.33	32	57.33	56
	Thigh	47.7	57.33	54.67	45.33	44	41.33	61.33*	42.67	38.67
	Knee	67.7	77.33*	61.33	68	70.67	58.67	74.67	60	61.33
	Lower Leg	55.1	66.67	64	40	44	50.67	69.33*	45.33	58.67
	Ankle	49.5	69.33*	53.33	38.67	41.33	30.67	66.67	49.33	44
	Feet	39.8	57.33	49.33	30.67	42.67	29.33	53.33*	25.33	38.67

*Highest percentage of discomfort in body part

discomfort in their lower limb; they feel more discomfort compared to other groups, lumber (62.67%), thigh (61.33%), lower leg (69.33%) and feet (53.33%).

4 Discussion

The study revealed that the Dhokra artisans are engaged in different crafting activities. For long periods of time, artisans perform various forms of intensive job, including uncomfortable postures, forward bending, and repetitive waist twisting, which may cause pain in various parts of their entire body.

Posture analysis study (Table 2) shows that postures adopted by the Dhokra artisans results MSDs. Therefore, it needs immediate changes by design intervention. This existing working condition impacts the occupational health and safety of the workers, productivity and quality of work, which increase their risk of developing posture-related MSDs [26]. According to the nordic score, It was noticed that the artisans were experiencing more discomfort in their upper limbs compared to lower limb, as shown in Table 3. The feelings of discomfort among the Dhokra artisans were related to MSDs like pain at upper arm (63.8%). Forearm (67.7%, Hand (69.1%) and Knee (67.7%). Awkward posture for an extended period of time and repeated waist twisting were observed in Dhokra activities. Study found in their study that floor-sitting sedge weavers also faced similar mix pain in their entire body [24] and due to that repetitive task, it's contributing to MSDs [27].

In Table 3, BPD score shows that artisans felt discomfort in their joints, but they suffered more during the work. Surface designing activity needs more precision which take much time and physical effort. This activity leads to more discomfort in upper limb during work. Similar results found in precision-based work like goldsmith [19] and brass metalwork [28]. Similarly, long duration of the repetitive moment become the cause of lateral epicondylitis in the forearm region [29]. These repetitive activities raise the chances of effect on the body's soft tissues by micro trauma and become the significant factor of disorders of injuries in future [30, 31]. The Dhokra artisans perform the hand based activity below their shoulder joint, but their shoulders are primarily affected by firing and pouring brass. Same time artisans felt pain in a lower limb due to carrying heavy loads and working in an awkward posture. A similar kind of result found in furnace brickyard workers [32] and welders [33]. According to research, low back pain has been linked to lifting heavy load in an awkward posture [34]. Bad working posture is mostly linked with the development of MSD as per the studies [35–37].

Due to covid protocols, we were unable to record the physiological parameters (heart rate, blood pressure, grip strength) of Dhokra artisans. The workplace also influences posture, which directly affects commercial products strength [38]. However working environment also affects artisans productivity; these parameters can consider for further study in workspace design [39].

5 Conclusion

Posture related MSDs are a significant issue to artisans in the Dhokra crafting activities, making work less enjoyable. Any design intervention will not be sustainable until it considers making work more humane. These research findings indicate that preventing the risk factors of posture-related MSDs in the unorganised sector of Indian handicraft required ergonomics design intervention. The correct approach for resolving these problems will give the right direction for the solution regarding work process and workstations design.

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Identification of Ergonomic Problem of Paddy Harvesting Due to Climatic Change at Small Scale Farms of Kerala, India

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Abstract Due to change in environmental weather condition and global warming for the last few years, giant tropical cyclones causes' massive damage to paddy crops mainly in the southern and eastern parts of India. Extensive damage to the crop by the cyclone and non-seasonal heavy rainfall causes enormous economic losses and crop reduction. Paddy harvesting is mainly done by female agricultural workers of southern India using traditional sickles. The time, effort and cost of harvesting paddy under these environmental conditions are double compared to regular paddy harvesting. Work-related musculoskeletal problems among the farmers due to paddy harvesting for changed weather condition is very high. An interview and questionnaire study was conducted among 28 agricultural workers to understand the existing ergonomic problem of paddy harvesting in these change environmental conditions. For data collection, small scale paddy farms from two districts of Kerala were selected in which harvesting is done in two different seasons. One place is rain-fed and the other is irrigated. The workers selected in this study reported pain in the upper arms and lower arms, followed by back and lower limb pain due to prolonged forward stooping and squatting posture due to harvesting lodged crops. This study will be helpful to draw insights into ergonomic problems in paddy harvesting in small scale farming with changed environmental weather conditions.

Keywords Heavy rainfall · WMSD · Climatic change · Paddy crop harvesting

1 Introduction

Rice cultivation occupies the most important agrarian economy of Kerala [1]. Lush green paddy fields are the most attractive features of Kerala and paddy fields are important in maintaining the environmental and ecological system of the state [2]. Paddy crops provide natural drainage for floodwaters and it protects groundwater and helps in conserving the flora and fauna [1, 2]. There are over 2000 varieties of

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Table 1 Kerala rice cultivation seasons in their local names and duration

Seasons		Period	
Local name	General	from	To
Virippu	1st crop/Autumn	Apr–May	Sept–Oct
Mundakan	2nd crop/Winter	Sept–Oct	Dec–Jan
Puncha	3rd crop/Summer	Dec–Jan	Mar–Apr

rice, grown all over Kerala, which is adapted to wide varieties of agro-ecological conditions [3].

Rice cultivation is done in three seasons in Kerala; Virippu, Mundakan, and Puncha mentioned in Table 1 [4] and there are two ways of irrigation been practised either rain-fed or irrigated. Kerala experiences the highest rainfall during June -July. However, for the last few years, massive cyclones and heavy rainfall are being seen during Virippu season, the period during paddy harvesting causing massive economic loss. Both small- and large-scale farmers are affected due to this unseasonal heavy rainfall. Highly climatic resistant paddy is also getting affected due to this unseasonal rainfall, resulting in the weak straw of the paddy crops. When a cyclone hits these paddy fields, the weak and affected paddy crops cannot withstand the wind speed causing lodging of the crops in different directions. A mechanized harvesting system fails to work in such conditions, and the farmers need to undergo manual harvesting. Manual harvesting of lodged crops takes more time and effort than the usual harvesting procedure. Manual harvesting of lodged paddy crops in the water-filled farm with long attains awkward posture results in acute work-related musculoskeletal discomfort.

In a study, the authors have stated that manual harvesting needs immediate investigation and changes [5]. Another study found that maintaining awkward posture for an extended period is the main reason for musculoskeletal disorder (MSD) [6]. There are many ergonomic studies on paddy crop harvesting [7–9], but very scarce literature is available on paddy crop harvesting with changed in environmental conditions. This study aims to conduct an ergonomic evaluation on manual harvesting and its effect on the farmers with the change in weather conditions.

2 Methodology

The study was conducted in two districts of Kerala: Mattannur situated at Kannur district and Kurivikadu, situated at Alappuzha district. A total of 28 respondents participated in this study. Data was collected from different stakeholders; farmers, farm owners, and the Krishi Bhawan, Mattannur, Kerala (State Government Agricultural Office). Interview and direct observation study were performed to collect data from different user groups. In Mattannur, to evaluate the condition of farm and harvesting difficulties due to heavy rainfall and cyclone, 15 respondents of the age group of 30–60 years were interviewed. In Kuruvikadu (Alappuzha District), 13

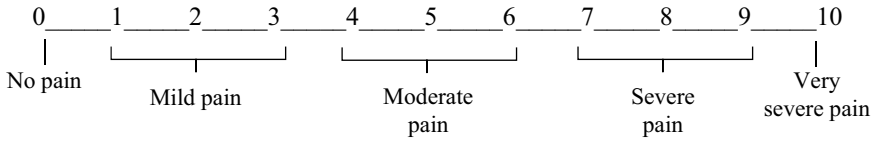

Fig. 1 Body Part Discomfort Scale (BPD)

respondents of the age group 35–70 years participated in the study. Modified Nordic Questionnaire [10] was used to identify body segments causing musculoskeletal discomfort. Body map along with Body Part Discomfort (BPD) scale [11] was used (Fig. 1) to measure the intensity of discomfort on different body segments. The scale consisted of 0–10 points where 1–3 represented mild pain, 4–6 represented moderate pain, 7–9 severe, and 10 were very severe. State Agriculture Department websites and data from research articles were used as the secondary data source in this study.

In Mattannur, out of three seasons, as shown in Table 1, first and second crop seasons are preferred for paddy cultivation. The study data from Mattannur was collected from the first crop season. In Kuruvkadu, only the third crop season was used to cultivate paddy. The two places were selected purposively based on two different paddy cultivating season, one is the first crop (Viripu) season, and the other is the third crop (Puncha) season. These two seasons are affected by unseasonal heavy rainfall and massive cyclones for the last few years.

3 Results

The paddy farm in Mattannur is not large enough to use both harvesters and reapers and lack adequate maintenance facilities (Table 2). For the past few years, it is reported that the percentage of lodged crops has increased drastically, leading to an increase in the number of labour forces for harvesting, as seen in Table 3.

In Kurivikadu, combine harvesters take 45 min to 1 h to harvest 1-acre paddy farm and mechanisation is ineffective for lodged paddy. Manual harvesting of lodged

Table 2 Area wise data related paddy cultivation

Place	Paddy verities	Crop season	Cultivation technique	Harvesting method	Area, hectare (ha)
Mattannur (Kannur District)	Ponmani, Uma, Athira	1st crop/Autumn	Rainfed	Manual (Sickle)	>1
Kuruvikadu (Alappuzha District)	Jyoti	3rd crop/Summer	Irrigated	Combine Harvester + Sickle	5–7

Table 3 Number of labours and time required to harvest paddy in different condition (Mattannur)

Mattannur (Kannur District), 1 acre of paddy farm				
Farm condition	% of lodging	No. of labours	Time to harvest (hours)	Labour charge/person (₹)
Normal weather condition	2–5	8	6–7	600–800
Changed weather condition	30–80	14–15	8–9	

Table 4 Number of labours and time required to harvest paddy in different condition (Kuruvikadu)

Kuruvikadu (Alapuzha District), 1 acre of paddy farm				
Farm condition	% of lodging	No. of labours	Time to harvest (hours)	Labour charge/person (₹)
Normal weather condition	2–5	4–5	5–6	500–900
Changed weather condition	60	14–15	8–9	

paddy was done to increase the yield resulting in a huge labour charge, as shown in Table 4.

All the respondents reported low back pain after harvesting (Fig. 2). In addition, 96% of harvesters reported discomfort in the wrist and hand. Furthermore, 89% of them reported discomfort in the knee and elbows, 78% reported ankle pain, 65% reported discomfort in feet, 58% reported discomfort in the shoulder, followed by 53% discomfort in the upper back and 50% discomfort in the neck.

Table 5 represents the total average intensity of discomfort feeling among farmers. The average rated discomfort reading was 8.9. This reading indicates that the farmers have severe discomfort feeling.

Interview with the farm owners and officials further revealed that the percentage of lodged crops' is getting worse compared to past years due to climatic changes. Lodging of the crops is happening at the matured stage of paddy harvesting due to massive cyclones and heavy rainfall (Figs. 3 and 4). The crops germinate within 3–4 days at the final stage, so harvesting on time is crucial. However, this situation causes huge labour costs, forcing the farm owners to abandon the affected part of the farm or convert the rice farm for other purposes for the next season.

4 Discussions

Despite all the technological advancements, still, manual harvesting is crucial for rice cultivation in Kerala. It is a highly manual intensive job. The study found that lower back, wrists, elbows and knees are the major body segments where the

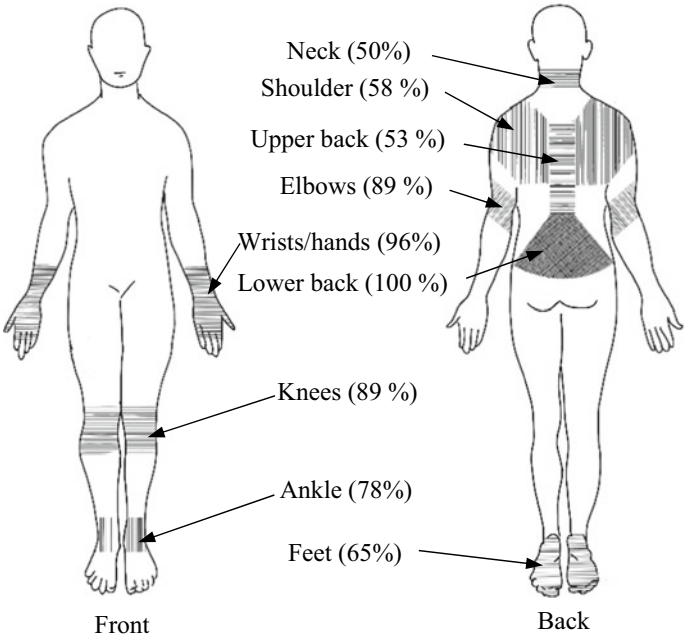

Fig. 2 Symptoms reported by the workers with the help of body map (n = 28)

Table 5 Body Part Discomfort (BPD) scale reading

Subject	No. of subjects	Average results of discomfort feeling (Pain) according to BPD scale	Remarks
		0____1____2____3____4____5____6____7____8____9____10	
Rice Farmers	28	8.9	The discomfort feel is severe among rice harvesters.

Fig. 3 Mattannur, paddy farm affected with heavy rainfall

Fig. 4 Kuruvikadu, paddy farm affected with heavy rainfall

farmers reported pain. The discomfort is mainly because of the harvesting paddy in an awkward posture for a prolonged period. The bend and squat posture for a long period causes muscle pain at different body parts [8, 12]. The results in Fig. 2 seem consistent with some of the other research findings [6, 13, 14]. Their study reveals that farmers' musculoskeletal disorders (MSD) are mainly because of the awkward working posture. In Table 5, the Body Part Discomfort (BPD) scale shows the average value of discomfort feeling among farmers as 8.9, which is in the severe discomfort range. Table 6 shows the comparative value of average Body Part Discomfort (BPD) scale reading in lodged condition and normal condition. The value for the lodged condition is higher than the Body Part Discomfort (BPD) scale reading in normal condition [6] which was 7.5. It may be because of the extra effort required to harvest lodged crops.

More than 60% of the paddy fields are affected due to the present climatic changes due to the global warming. Among the four paddy varieties shown in Table 1, which are cultivated in two places (Mattannur and Kurivikadu), the two varieties Uma and Athira are non-lodging breeds [15]. These hybrids are also getting lodged due to massive cyclones and heavy rainfalls. The effort required to harvest lodged paddy in the muddy field before germination is very high and that may be the reason for the

Table 6 Body Part Discomfort (BPD) scale reading in different condition

Subject	Condition	BPD scale Result	Remarks
Rice Farmers	Lodged	8.9	The discomfort feel is severe in lodged condition
	Normal [6]	7.5	

severe discomfort rate among the harvesters shown in Table 5. Moreover, the farmers are backing out from harvesting in these conditions due to the extra effort leading to severe bodily discomfort and economical losses. Further ergonomic study is required in the coming harvesting months to find out possible ergonomic interventions to solve this problem and to reduce future losses.

5 Conclusion

According to Maslow's hierarchy of needs, food is the basic needs of human. Change in environmental weather conditions and global warming lead to massive cyclone and unseasonal rainfall affecting the food chain in Kerala. Ergonomic design intervention to counteract the effects of harvesting lodged crops is the need of the hour to protect from losses of rice cultivation.

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Analysis of Transplanting Activity Using Surface Electromyography

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Abstract Transplanting activity involves women to work continuously in a bent posture resulting in musculoskeletal disorders. Muscle fatigue in the human body while performing a task can be studied using surface Electromyography. The experimental study was conducted among four healthy female subjects and they performed both methods of transplanting namely conventional method and with use of hand held seedling transplanter on ridges and furrows in a simulated environment. The mean MVC of the subjects were assessed prior to the start of the experiments using standard protocols. The percentage of changes in the sEMG for Abductor pollicis brevis, Extensor, Biceps, Trapezius was −15.9, −5, 2.2, 8.4 for right side as against −23.8, −3.0, −6.1, 3.9 for the left side while using Hand Held Seedling transplanter over the conventional method respectively. Analysis of the sEMG indicates that introduction of a simple tool such as Hand held seedling transplanter would result in avoiding awkward postures and reduction in the muscle fatigue and thereby increases the productivity of women in Agriculture.

Keywords Transplanting · Farm women · Electromyography · Agriculture · Transplanter

1 Introduction

Agriculture is the primary source for food and also provides inputs for various industries. In India, female agricultural workers constitute 50.2% of the total agricultural

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work force. Women do extremely tedious, time and labour intensive works like sowing, transplanting, weeding, harvesting, threshing, plucking and post harvest operations etc. Inadequate working methods, heavy physical work, improper tools and working techniques results in unnecessary fatigue and increases occupational accidents leading to low productivity.

It has been widely acknowledged in various research studies, that designs made without users' anthropometric dimensions results in mismatch between the user and the equipment designed, resulting in various discomforts to the users. Several studies have documented the medical problems faced by the workers due to the mismatch between the work, worker and environment. Designs created for a specific region/ specific user population needs to be refined to suit other users. Thus, designs of equipment for various agricultural operations needs to be designed based on user population.

Seeding and transplanting operations which are performed manually account for 40% of total working hours of cultivation. The traditional practice is to hold a bunch of seedlings/seedling tray in one hand and separate seedlings in the other hand and press down the roots in the soil with bare hands. The work is laborious and drudgery prone as the operation is done in a bending and squatting posture. The labour requirement in manual transplanting of vegetable seedlings varies from 120 to 420 mhr/ha [1, 2]. As the vegetable crops are sensitive to high temperature and require timely operations, transplanting should be completed as early as possible after removing the plants from the nursery. However, labour shortage during peak season causes delay in transplanting leading to mortality of seedlings and eventually yield loss.

The repetitiveness of the work, prolonged working hours and awkward body postures during work may lead to musculoskeletal disorder in farm women. Muscle fatigue is a common physiological symptoms experienced by their daily activities. Muscle fatigue refers to the inability of a given muscle to produce force or failure to maintain the desired force and it is normally associated with localized pain. Accumulation of lactic acid in the muscles during work leads to glycogen depletion. This glycogen depletion hinders the contractile properties of the muscle which results in muscle fatigue. The various risk factors contributing to the MSDs in different agricultural tasks have been studied [3–7].

The changes in the muscle contractile could be studied using surface electromyography. The surface electromyography gives valuable information about muscle fatigue by detecting changes in time domain parameters, frequency domain and wavelet transformation. Thus, the electrical activity of the muscle could be recorded non-invasively using electrodes placed on the skin.

The pilot study has been carried out to investigate the muscle activity during different methods of transplanting vegetable seedlings namely—conventional method and by use of ergonomically designed hand held seedling transplanter.

2 Methodology

2.1 Selection of Subjects

Four healthy female subjects who were willing to participate in the study were purposively selected. The age range of the subjects varied from 19 to 21 years and they reported no major health issues. The details of the experiment conducted were clearly explained to them and written consent was obtained from the participants to participate in the study. The study was conducted in accordance with the institutional review committee of the university. They were compensated for participation in the study.

2.2 Selection of Activity

Transplanting of vegetable seedlings was selected for task analysis. Two methods of transplanting namely conventional method and by use of an ergonomically designed handheld seedling transplanter (developed by the institute) were evaluated using surface electromyography. The conventional method of transplanting was through placing the seedling using the traditional tool with a handle on one side (Fig. 1). This posture is referred in the study as a conventional method. The subject was asked to perform the activity of seedling transplanting using ergonomically designed transplanter (Fig. 2) for 30 min. Prior to this experiment they were given training on use of handheld seedling transplanter to get acquainted. On practice and after gaining confidence on use of the designed tool, they participated in the experiment.

Fig. 1 Conventional tool

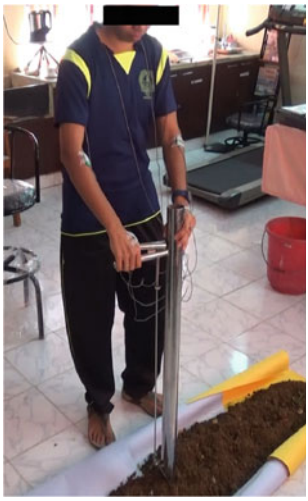

Fig. 2 Hand held seedling transplanter

Following this adequate amount of rest was given and the subjects were asked to do the experiment. The entire experiment was conducted during the forenoon section from 8.00 am to 12.00 noon in a simulated condition.

2.3 Recording of sEMG

Surface Electromyography (sEMG) is a non invasive procedure involving the detection, recording and interpretation of electric activity of group of muscles at rest (i.e. static) and during activity (i.e. dynamic). For recording sEMG, Biometrics UK model Data LOG, MWX8, with EMG pre amplifier (SX2301000) was used for the study. Skin preparation techniques namely cleaning was done using spirit to remove oil and surface residues and the skin was allowed to air dry for a few seconds. The locations of the sensors were positioned using the SENIAM recommendations. Myoelectric signals were detected from each muscle using a linear array of 8 electrodes and a ground strap. Sensors were placed in the following muscles; Right abductor, Left abductor, Right flexor, Left flexor, Right trapezium, Left trapezium, Right biceps, Left biceps. The muscles were selected based on the activity namely—piercing the transplanter into soil, placing of seedling, releasing of lever of the handle, lifting the transplanter and moving. Since these action required—lifting, gripping, releasing the following muscles were selected—Abductor policis brevis controls the abduction of the thumb anteriorly: flexor is mainly used for gripping action; trapezius is used for supporting the arm, biceps is involved in flexion of the elbow and supination of the forearm. Hence these four muscles of both sides were selected.

The Maximum Voluntary Contraction (MVC) of the selected four muscles namely Abductor pollicis brevis, Extensor, Trapezius and Biceps were estimated using the standardized tests. Subjects were asked to perform the planting of seedling using

Hand-held seedling transplanter on a stimulated environment representing the ridges and furrows for a period of 30 min. Following this, the subjects were allowed to rest for 30 min. The subjects were asked to perform the planting of seedling in a conventional manner for 30 min. The signals were recorded using data logger and a system. The sEMG of each muscle was expressed as a percentage of the MVC of the muscle.

3 Results and Discussions

The details of the selected subject are presented in Table 1. Participants in the age range of 19–21 were purposively selected. The height of the subjects ranged from 159 to 170 cm with weight of 45–55 kg. Based on the height and weight the BMI was calculated and it is observed that the majority of the subjects had normal BMI and one subject was underweight.

The musculoskeletal discomforts of different agricultural tasks have been studied by the different researchers and the risk factors include age, task involved, time, posture etc., Studies [8–11] clearly indicate that transplanting is one of the activities that involves bending for long time and planting seedlings in a bent posture results in pain in the neck, shoulders, hands and legs. Observing the transplanting activity indicated that the worker used the dominant hand to iterative gripping, while the non dominant hand is only involved in holding the seedlings.

The mean MVC of the selected muscles for all the subjects is presented in Table 2. Studies clearly indicate that transplanting is one of the activities that involve bending for long time and planting seedlings in a bent posture results in pain in the

Table 1 Details of the subjects selected for the study

Subject	Age (yrs)	Height (cm)	Weight (Kg)	BMI (kg/m^2)
1	20	162	50	19.1
2	19	160	50	19.5
3	21	159	46	18.2
4	21	169	55	19.3
Mean ± SD	20.25 ± 0.95	162 ± 4.45	50.25 ± 3.68	19.02 ± 0.57

Table 2 MVC of the selected muscles (mean ± SD)

Muscles	MVC (right) (mV)	MVC (left) (mV)
Abductor pollicis brevis	0.0383 ± 0.016	0.0394 ± 0.011
Extensor	0.1683 ± 0.117	0.1785 ± 0.148
Trapezius	0.1117 ± 0.059	0.1403 ± 0.168
Biceps	0.2642 ± 0.135	0.2596 ± 0.751

neck, shoulders, hands and legs. Video graphic analysis of the transplanting activity indicated that the worker used the dominant hand to iterative gripping, while the non dominant hand is only involved in holding the seedlings.

It could be observed from the table that there was not much difference between the MVC of the selected muscles on either side. However individual analysis indicated that higher MVC was observed in the dominant hands and also variation could be observed amongst the subjects MVC.

The changes in MVC during different methods of transplanting namely conventional method and also by using hand held seedling transplanter is presented in Figs. 3 and 4. It could be observed that there is great reduction in the strain of the Abductor policis brevis with the use of transplanter. A similar trend could be observed in the use of extensor and biceps muscles too. Thus it could be inferred that use of hand held seedling transplanter to transplant seedlings have been effective in minimizing the fatigue of women.

Use of properly designed devices for various agricultural operations such as harvesting [6] will help in minimizing the MSD's experienced by the workers. Kumar [4] evaluated garden raking with different types of rake. Among males during pulling activities the left erectores spinae (at L, and L3 combined) was more active which contributed to 22–34% of total muscle load compared to the right erectores spinae. However, in pulling activities, left external oblique and left rectus abdominis contributed 12–22 and 15–20% respectively. Their right counterparts contributed 2–6 and 7–13% respectively.

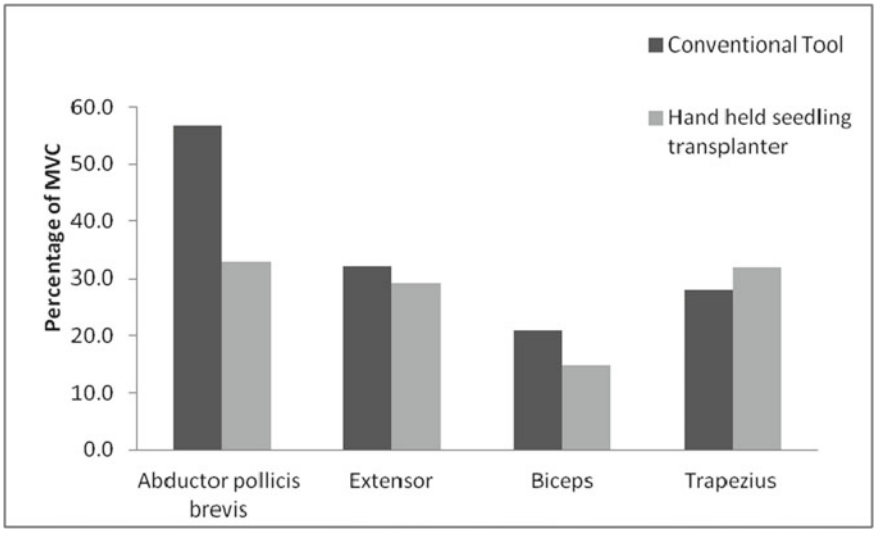

Fig. 3 Changes in sEMG in left side

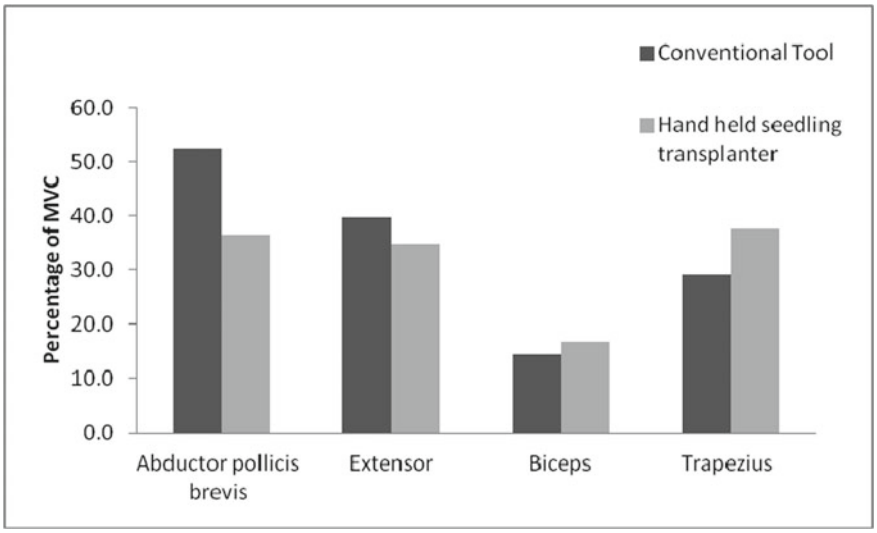

Fig. 4 Changes in sEMG in right side

4 Conclusion

There is a wide spectrum of shown or suspected work-related musculoskeletal disorders (WMSDs), affecting various anatomical structures in different parts of the body while carrying out agricultural activities. Efforts are needed to introduce locale specific simple women friendly tools to minimize the fatigue. The present study attempts to highlight the beneficial effect of moving towards ergonomically designed tools to alleviate drudgery of farm women.

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The Effects of Training with Two Smartphone Games Based on Stroop Effect and Reaction Time on the Processing Speed: A Pilot Study

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Abstract This study investigates the impact of cognitive training on young adults using two smartphone games based on Stroop effect and reaction time respectively in Indian young adults. Similar studies are rare in the Indian context. In a pilot study, a randomized controlled trial was conducted on twelve college students using Spot the Number and Stroop Effect Challenge Android games available in Google Play Store. The twelve participants took a pre-test of digit symbol substitution test (DSST) and symbol search test (SST) and their performances in these standardized tests were recorded. Six participants each were randomly assigned to a training group (TG) and a non-training group (NTG). Participants in TG played the two games three times each day for twenty-one days. After this training regimen, a post-test was conducted on the twenty-second day. An increase in the mean score of the NTG by 4.59% in DSST and 4.44% in SST was observed; while the increase in mean scores of the TG was found to be 18.29% in DSST and 16.35% in SST. After twenty-one days, statistically significant difference was observed in the performances of both the TG and NTG in the two standardized tests.

Keywords Android smartphone game · Stroop effect · Reaction time · Digit symbol substitution test · Symbol search test

1 Introduction

Processing speed is related to the time in which a brain takes new information and responds to the stimulus. Studies show that the processing speed of information differs with age represented by an inverted U-shaped curve [1]. Our cognitive processing speed increases from childhood to adolescence and then is relatively stable up to the middle age. After the late median age, processing speed declines slowly but steadily [1]. Slow processing speed due to age afflicts a significant number of people. It is commonly observed that older individuals take a longer time to respond cognitively as compared to their younger peer group. Some studies suggest that the

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wear-tear of white matter's in the brain, which consists of axons that link one part of the brain to another, is the cause of deceleration in information processing speed due to ageing [2].

The processing speed is considered as one of the primary sources among the four factors (processing speed, processing capacity, knowledge, skills) that affect the human performance in cognitive tasks [3]. The processing speed is built on the type of intelligent functions such as scanning ability, pattern recognition, complexity, and memory [4]. Processing speed declines when an adult exceeds the middle age, and it also depends on the gender since females have been found to exhibit higher processing speed [5]. Also, slow processing speed is identified with different clinical conditions such as attention deficit hyperactivity disorder (ADHD), Autism spectrum disorder (ASD), oppositional defiant disorder, anxiety disorders, mood disorders, and conduct disorders [6].

Earlier studies have found that cognitive tasks training can improve the cognitive functions in individuals. There are different kinds of cognitive trainings such as processing speed training [7], strategic memory training [8], working memory training [9], and brain training games [10].

The claim of advantages of cognitive training on cognitive function been has met with different perspectives. Some studies revealed that brain training games increase cognitive functions in older adults [11], but not in young adults [12]. Also, some studies have found that brain training games increase cognitive function in both young adults and older adults [10, 13]. It is also claimed that processing speed training gives the benefits after a few years [14]. Studies have also found that processing speed training shows improves health-related quality of life [15] and helps in managing depressive symptoms [16, 17]. A relationship between general intelligence and the speed of performing simple mental operations has also been found [18, 19]. In addition to this, processing speed training is also associated positively with cognitive and everyday functions [20]. Studies also indicate an improvement in cognitive functions by playing video game and cognitive training in young adults [21–23].

Stroop effect is commonly understood as the delay in reaction time between congruent and incongruent stimuli. Therefore, it might refer to the observation that it takes longer time for a person to name the color of ink while simultaneously reading words denoting incongruent color names than in the case of reading neutral words or words that denote a congruent color. For example, if the word blue is written in red ink (incongruent), participants take longer to say "red" than if the word glue is written in red ink (neutral) or if the word red is written in red ink (congruent). In this context, reaction time is the time that elapses between the onset or presentation of a stimulus and the occurrence of a specific response to that stimulus [24]. Transfer effect is referred to as an improvement in the cognitive functions by playing video games [25]. As a consequence, brain training games like Brain Age, Brain Challenge, Spot The Number and Stroop Effect Challenge find popular use [10]. These brain training games have proven beneficial effects on cognitive functions [10, 13].

Processing speed can be measured by using Digit Symbol Substitution Test (DSST) and Symbol Search Test (SST). Both these are sub-tests of the Wechsler Adult Intelligence Scale (WAIS) [13, 26, 27]. During DSST, an individual has to

copy (with a pen or pencil) a symbol in the blank box under a specific digit (1–9) by looking at the key provided at the top of the sheet where the digit and its corresponding symbol is already printed. For conducting SST, two target symbols which are printed on the left side of a sheet of paper are expected to be found among the collection of five symbols on the right side of the sheet in the same row. The individual responds by identifying and marking the identical symbol. If the identical symbol is not present, then the individual has to check the "NO" option box. As compared to healthy young adults, the score on SST is found to reduce by 50% between the age of 25 and 65 [28].

In the past, many such studies have been conducted in different contexts outside of India. However, a greater access and acceptance of digital devices in India provides an opportunity for implementing games-based cognitive trainings easily in India as well. Such trainings could improve the reaction times and processing capacities of young adults who face especially challenging academic competition at the professional degree level. This study investigates the effects of playing cognitive training games aimed at Stroop Effect and reaction time, on the cognitive processing speeds in healthy young adults in a pilot setting in India.

2 Methodology

2.1 Participants

Twelve college students studying Engineering at the undergraduate (UG) and postgraduate (PG) levels volunteered to participate in this study. While recruiting for the experiment, it was ensured that the participants had no previous exposure of the digital games used for cognitive training, or the DSST and SST tests. The participant age range was 23–28 years (Mean = 26, SD = 2.82). Eight participants were male and four were female. The smartphones used by the participants for the training offered same processing speed experience during game playing.

2.2 Procedure

During the pre-test, DSST and SST were administered on the twelve participants and their performances were recorded. These tests were conducted using the methodology published by the National Institute on Aging, USA [29]. The duration of DSST and SST was 60 s and 90 s, respectively.

After the pre-test, the participants were divided randomly into two groups, one training group (TG) consisting of six participants and a non-training group (NTG) constituted of the other six participants. The TG participants were required to install two popular games available Google Play Store namely Spot the Number (source:

Hashtag Games) and Stroop Effect Challenge (source: Wesley Dungan) on their Android-based smartphones [30, 31]. Spot the Number is a fast response game in which the players have to find and point to a number as fast as possible. The score increases if the player taps on a tile with the same number on it as is also showing at the lower end of the screen. A wrong tapping will decrease the score. This game basically improves hand–eye coordination, which is a technique known to improve the reaction time. Stroop Effect Challenge is a game based on an observation by John Ridley Stroop that incongruent stimuli make doing a certain task more difficult [30, 31]. In this game, thirty words are presented sequentially, and the player has to identify as quickly as possible, which colours were used to display each word.

For 21 days, the participants were instructed to play these games 3 times each day during those periods of time when they perceived that their brain was highly active. Decision regarding the duration of training was based on the duration in related research works. Studies have made use of game based training schedules of duration 4 weeks with 5 training days per week [10, 13, 17]. A data collection sheet was provided to these participants where they documented their game scores for each day. At the end of 21 days, a post-test consisting of DSST and SST was conducted for participants from both the TG and NTG groups and their scores were recorded for analysis.

The entire study was conducted in conformance to the protocols of the Institute Ethics Committee (IEC), NIT Rourkela (India). All the data collected was anonymized to ensure protection of participant identities.

2.3 Data Analysis

An independent sample t-test was performed to know the significant difference between the TG and NTG groups [32]. Cohen's d value was also calculated to find the effect size estimates [33]. An ANCOVA test was conducted using the difference between the post-test and pre-test scores in the case of both DSST and SST [13]. Statistical analysis was performed using IBM SPSS Statistics 24 [34]. An ANCOVA analysis was conducted where the change in the scores was the dependent variable, groups TG and NTG were the fixed factors, and the pre-test score was the covariate.

3 Results

The t-test revealed that there was no significant difference ($p < 0.05$) in the test scores of the TG and NTG groups before the training (Table 1). Cohen's d was found to be less than 0.20 and therefore the effect size was regarded very small [35]. Table 2 shows improvements of the processing speed in TG as compared to NTG. The effect size (η^2) for both DSST and SST was found to be large [35].

Table 1 Pre-test, post-test performances and comparison among pre-test performances

Test name	TG		NTG		Pre-test scores comparison t-test results	
	Pre-test	Post-test	Pre-test	Post-test	Effect size(d)	Significance (p)
	Mean(SD)					
DSST	41 (3.03)	48.5 (3.27)	43.5 (1.76)	45.5 (1.87)	0.07	0.18
SST	25.5 (7.28)	29.67 (5.78)	26.33 (3.38)	27.5 (2.074)	0.14	0.34

Table 2 Results of ANCOVA analysis for both TG and NTG

Test name	Difference in post- versus pre-test for TG		Difference in post- versus pre-test for NTG		Result of ANCOVA analysis	
	Mean	SD	Mean	SD	Effect size (η^2)	Significance (p)
DSST	3.5	1.64	0.33	1.86	0.49	0.016
SST	4.16	1.72	1.16	1.83	0.4	0.002

In Table 1, an independent-sample t-test comparision of the pre-test scores of DSST and SST revealed that there is no significant difference in between TG and NTG groups. Effect size estimates was calculated by using cohen's d and were found to be fairly small (d values of about 0.20 is understood as small effect; 0.50 as medium effect and 0.80 as large effect).

In Table 2, the change in score was calculated by subtracting the pre-training score from the post-training score. ANCOVA test was conducted for the change in score and the pre-training score was taken as the covariate. Level of significance was set at 5%. Effect size as a descriptive index of strength of association between an experimental factor (main effect or interaction effect) and a dependent variable, is defined as the proportion of total variation attributable to the factor. Effect size was found to be large for both DSST and SST test results. Its value around 0.01 is regarded as a small effect, around 0.06 as medium effect, and around 0.14 as a large effect. This means that the game based training interventions in this study yielded significant reaction time related performance benefits.

4 Discussion

Various studies have shown that different cognitive trainings can help to improve human information processing capabilities which can be measured by tests such as DSST and SST. In this study, the training based on Stroop was focused on increasing the cognitive flexibility and brain plasticity. This reflected in the improved scores in the DSST and the SST. This might be explained by a possible involvement of

similar brain structure (cortical areas) for the Stroop effect, DSST and SST. Previous studies have shown that processing speed training will help to improve the processing speed measured by DSST and SST [10, 13, 17]. This study has similar findings with recorded improvements of DSST and SST scores after processing speed training.

It should also be noted that this study is not conducted for a long-term period and the training duration effect on processing speed was not within the scope of this

Table 3 Comparison with previous studies

References	Location and nature of training	Duration of training	Tests and analysis conducted for processing speed analysis	Pre- and post-test results	Remarks
[10]	Japan, brain training by playing Brain Age versus Tetris	4 weeks	DSST (Cd), SST (SS), MANCOVA	Cd, $F(1, 12) = 11.74$, $\eta^2 = 0.19$, $p = 0.005$; SS, $F(1, 12) = 8.22$, $\eta^2 = 0.12$, $p = 0.014$	Improved processing speed in the elderly by playing Brain Age
[13]	Japan, brain training by playing Brain Age versus Tetris	4 weeks	DSST (Cd), SST (SS), ANCOVA	Cd, $F(1, 27) = 9.46$, $\eta^2 = 0.23$, $p = 0.006$; SS, $F(1, 27) = 9.65$, $\eta^2 = 0.24$, $p = 0.004$	Improvement in processing speed in young adult by playing Brain Age
[17]	Japan, processing speed training by playing processing speed training game (PSTG) versus knowledge quiz training game (KQTG)	4 weeks	DSST (Cd), SST (SS), ANCOVA	Cd, $F(1,67) = 6.05$, $\eta^2 = 0.08$, adjusted $p = 0.03$; SS, $F(1,67) = 6.63$, $\eta^2 = 0.08$, adjusted $p = 0.03$	Improved performance in processing speed in healthy elderly people by playing PSTG
This study	India, processing speed training by playing Spot the Number and Stroop Effect Challenge versus non-training group	3 weeks	DSST, SST, ANCOVA	DSST, $F(1,12) = 8.76$, $\eta^2 = 0.49$, $p = 0.016$; SST, $F(1, 12) = 19.99$, $\eta^2 = 0.4$, $p = 0.002$	Improved performance in processing speed in young adults people by playing the games

work. Previous studies have also shown that the performance of DSST and SST are also affected by a different cognitive process i.e. memory [36]. Effect of memory has not been specifically studied in this work but the authors do understand that the individual memory specific cognitive faculty might have an important role in affecting test performance results.

In relation to the observations made in previous similar studies, Table 3 provides a comparision with this study. The effect sizes observed in this study are fairly high as compared to the past research which might be due to user specific differences. In this study, Indian users with no experience at all with cognitive training tools had participated and were found to benefit enormously by the training imparted.

5 Conclusion

A specific kind of cognitive training regimen was implemented and evaluated in this work to understand the usefulness of cognitive training in improving human information processing performance of young adults in India. The results and inferences from this work have direct implications for design of work systems and human performance, adding to the body of knowledge associated with ergonomics or human factors.

The results of this paper support the observation trends of different previous findings, demonstrating an improvement of DSST and SST scores after imparting processing speed training in Indian settings. It was found that playing games based on the Stroop effect and reaction time training in a time period of 21 days led to improved processing speed performances by 18.29% in DSST and 16.35% in SST for Training Group.

One specific limitation of this study is the small user sample size and therefore there exists a possibility to replicate this study with a larger user sample for more reliable and generalizable inferences. Also, this study has largely been conducted for a young adult population and there exists a possibility of extending this research to other age groups as well. Also, this study has been conducted using a limited training period of 21 days; therefore, it could be suggested to observe the results of similar training regimen on the processing speed performance in long-term training conditions.

The effects of additional control parameters could also be observed in the future as the performance of DSST and SST could also be affected by a different cognitive process like memory [36]. Neurophysiological assessment of the brain activities (like EEG, fNIRS etc.) at the time of training period and during the pre and post-test could also yield valuable insights into the results from this work. Past studies show a long-term benefit of training on cognitive functions which could also be explored in the future [37].

Declaration This paper has been developed from the major-thesis work submitted by the first-author at Industrial Design department, National Institute of Technology, Rourkela submitted during May, 2021.

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Fishbone Diagram Analysis for Assessing Ergonomic Risks in Onshore Oil Rig Operations

Alex Bernard and G. Varaprasad

Abstract Oil producers are always keen on ensuring safety standards followed in oil rigs and adheres to it during crude oil extraction. Global economy still relies heavily on petroleum production even though renewable energy sources are playing a vital role. Onshore oil rigs are used to extract crude oil from underneath the earth surface. As the working environment is more challenging and riskier in operations, ergonomic interventions are accepted by most of the companies. Despite the safety culture and large-scale modernization, still the industry shows high ergonomic risks and leads to musculoskeletal disorders to workers. Fishbone diagram analysis is a graphical tool used by many organizations for making diagnoses or taking concrete actions in which, the root cause of the problem is identified. The present study analyses the ergonomic risks associated with onshore oil rigs using fishbone diagram analysis and assess the risk factors based on machine, method, materials, measurement, man and environment. In-addition, the study presents the ergonomic risks in mud mixing operations using fishbone diagram. The study leads to guide the occupational experts to judge the risk levels and to develop risk mitigation plans.

Keywords Onshore rig · Crude oil · Fishbone diagram · Mud mixing operations

1 Introduction

The extraction of crude oil from trapped location beneath the earth surface is a challenging technical activity exercised by oil and gas companies for long time. These deposits can be extracted by drilling through the impermeable rock into the permeable rock.

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1.1 Oil Rigs

The Oil rig is a collection of machine systems that helps in the extraction of oil as well as natural gas from the land and seabed. Every oil rig production is based on different purposes and has unique features. As oil and gas are being the essential commodities, companies are heavily dependent on extensive extraction through drilling to increase its supply [1]. The rigs used in land are called onshore rigs and in turn used in seabed are called offshore rigs. To start exploring a field, rig is to be moved to that location and exploratory well operations are carried out. Later multi well production platforms are installed for producing oil and gas. On a world level, the number of onshore rigs is more compared to offshore rigs. The world level statistics of operational rigs till the year 2019 shows approximately 1629 rigs belongs to onshore and 280 rigs to offshore rigs [2]. The crude oil is an important energy source which plays a vital role in our society and the generated petroleum products serves as a feedstock for several consumer goods. Mostly, the oil rig operations need long hours of work, heavy and large equipment or sometimes hazardous materials which in turn provides high risk to the workers. Figure 1 shows the major parts of an onshore rig.

Fig. 1 Onshore rig [3]

1.2 Rig Operations

There are generally two types of rigs: drilling rigs and workover rigs. The drilling rig operations needs exploratory drilling and at the end of it a well will be ready for crude oil extraction. The workover rigs are used for well servicing and remedial engineering which provides production enhancement of the entire life cycle of the rig. Every rig is accompanied by vast paraphernalia like engines, generators, mud tanks, shale shakers, degasser, desander etc. In onshore rigs these equipment's are scattered over a large area and connected each other to carry out the operations in an effective way [4]. Nearly 12–16 workers will be available to do the drilling operations in an exploratory well site. To increase the safety of people working on the rig, the drilling industries have tried tremendous modifications in rig design and layout, by safeguarding the environment [28]. This resulted in improved efficiency in drilling the well [22].

1.3 Risks in Rigs

Oil rig workers face different types of challenges, from basic structural to environmental hazards associated with different the chemicals used for execution of their jobs [26]. Fire explosion is one of the major risks faced by the drilling industry. Moreover, petroleum itself is a highly flammable substance. In addition to that several hazardous chemicals are also regularly used for routine operations. Sometimes, a too much pressure in the well may lead to fire explosions [27]. Another concern is falls and associated accidents due to the use of several hazardous machinery which can pose dangers to workers. Another very important risk factor that slows down the reaction time and increases the likelihood of an accident is fatigue due the prolonged working in the uncomfortable environment [19].

The recent report published by International Association of Oil and Gas Producers (IOGP) indicates that the industry experienced 25 deaths among member companies in the year 2019. The causes of death are by "caught in, under, or between" incidents, which excludes those involving dropped objects [5]. Incidents involving lifting, crane, rigging, and deck operations were the main cause of deaths [25]. Ergonomics injuries fit into the categories titled "Overexertion," "Other" and "Bodily Reactions". Most of the accident types comes under ergonomic categories [6]. Therefore, it is very important to consider the ergonomic risks associated with all the phases of operation that cause injury to the workers and affects the production. Worker ergonomic and safety awareness is necessary for injury prevention during all phases of drilling operations [20]. Fishbone diagram is a tool that analyses the effects and causes that contribute to above mentioned risks [7]. The study investigated the ergonomic risks associated with onshore oil rig operations using fishbone diagram method. In addition, the study included fishbone analysis on mud mixing operation.

2 Materials and Methods

For risk identification and analysis various tools are available in industry namely check sheets, flowcharting, process mapping, fishbone diagram, hazard operability analysis (HAZOP), hazard analysis and critical control point (HACCP) etc. [18]. The proposed study uses fishbone diagram for the risk identification.

2.1 Fishbone Diagram

Fishbone diagram is a graphical tool used to analyze the affecting factors that determines the characteristics of work output quality. This method identifies the root causes attributed to the problem by listing them systematically [8]. The standard diagram has "bones" like fish skeleton representing Manpower, Machine, Methods, Materials, Measurement and Environment with offshoots on each bone by identifying contributing causes [9]. The classification framework encourages the identification of contributory factors from an individual to an organizational level [10]. The decision makers need to see beyond the risk evaluation. The generation of the risk-information is often supplemented with decision analysis tools such as cost–benefit analysis, cost-effectiveness analysis and multi-attribute analysis [11]. The data acquisition for the study was done in consultation with various rig contractors and personal meetings with workers from oil rigs. A thorough literature review was initially conducted to identify the risk factors affecting the performance of the oil rig operations [12]. The current study used 5 M + E method for analysis. In 5 M + E method 5 M's are Man, Measure, Material, Machine, Method and E is representing Environment. The general structure of a fishbone diagram is shown in Fig. 2. The head part of the fish shows the effect and bone structure shows the causes [30]. The six protentional causes of risk possibilities are listed in each bone using 5 M + E method and subsequently the sub causes are listed in each bone structure as cause 1, cause 2 respectively.

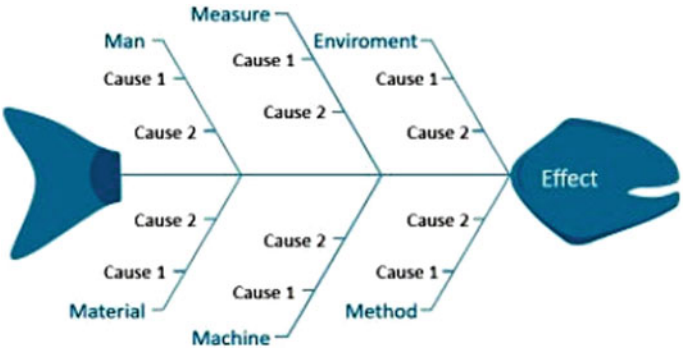

Fig. 2 Structure of a fishbone diagram [13]

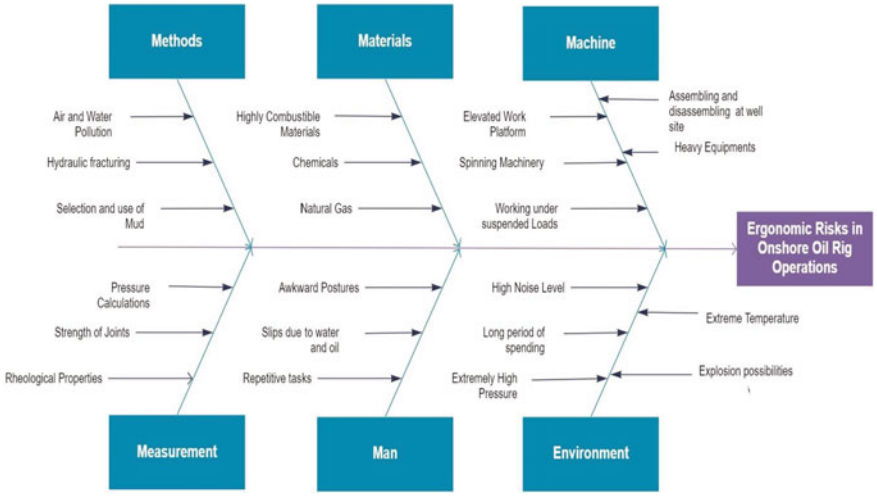

Fig. 3 Fishbone diagram of ergonomic risks in onshore rigs

2.1.1 Ergonomic Risks in Onshore Oil Rigs

The ergonomic risks associated with the usage of machines, materials, methods, measurement, man and environment are shown as fishbone diagram in Fig. 3. The studied effect or negative problem is the fish head (Ergonomic risks in onshore oil rig operations) and the potential causes (Machine, Materials, Methods, Measurement, Man, Environment) along with sub causes (indicated in black arrows) defines the fishbone structure [14].

The data used for the analysis were collected from rig visits, literature, safety magazines and discussion with engineers and workers from oil rigs. The significance of any given factor cannot be understood by evaluating the direct relationships between factors but must be evaluated considering the direct and indirect influences throughout the entire network of causal linkages [15].

2.1.2 Ergonomic Risks in Mud Mixing Operations

The drilling fluid commonly called 'Mud' is circulated throughout the drilling operations. The circulation system moves the fluid down to the drill stem, out of the bit and back up to hole to surface. The mud mixing operations involves lot of manual material handling operations like lifting, carrying, lowering, pulling etc. [24, 25]. The repetitive operations lead to musculoskeletal disorders among workers. Figure 4 shows the fishbone diagram generated for analyzing ergonomic risks in mud mixing operations [21]. Motivated by the studies from literature [16, 17], the study organized the related factors and their interrelationships.

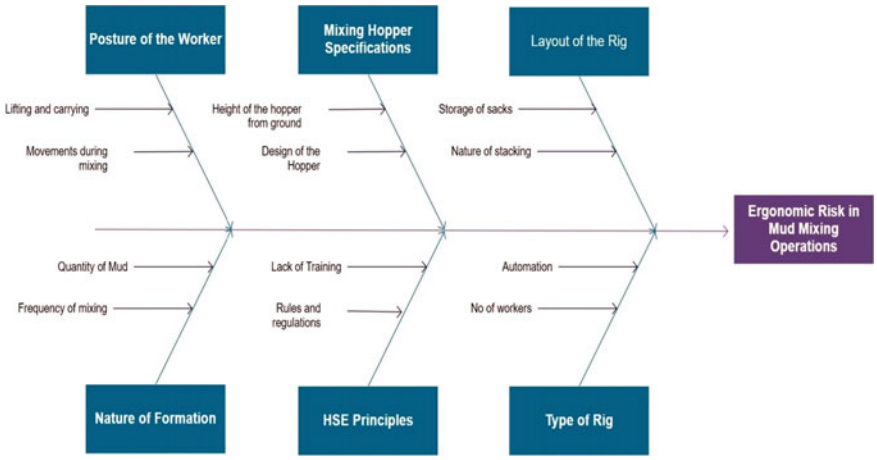

Fig. 4 Fishbone diagram of ergonomic risks in mud mixing operation

The risk factors identified through fishbone diagram helps for risk management and decision-making process [8]. Here, the fishbone diagram acts as a Quality Risk Management (QRM) tool [9] helping in identifying the potential issues, hazards, defects, bottlenecks and restrictions [23].

3 Result and Discussion

It can be observed from Fig. 3 that, the sub causes identified are more from Machinery and Environment. For Onshore rigs, the major ergonomic problem arises from the machinery used during rig operations. The onshore rigs consist of heavy equipment and moving them from one place to another increases the risks. The sub structure of the oil rigs is elevated from ground level, mostly above 30 feet, which increase the chances of accidents especially falling from heights. Most of the fatalities ensues when the rigs are being assembled or disassembled at the well site or when drill pipe was inserted or removed from well bore. In onshore rigs most of the equipment are spinning and supporting equipment like cranes and forklifts which are frequently in motion on a job site. Here, the risk arises when working under suspended loads, around unguarded equipment or moving parts of equipment, or when working with pipes, casings, tongs, elevators and springs. Mostly the workers are exposed to wide variety of rotating well head equipment's including top drives, draw works, pumps, hoist blocks and connections.

Another risk factor in rig sites are the hazardous materials that are used as chemicals for drilling fluid preparation. The process itself is using highly combustible material which has high severity of risk. Sometimes, during the drilling process chemicals such as hydrogen sulphide may come out and which in turn increases the

chances of blowouts. Crude oil itself is perilous in nature which need to be managed carefully during transportation from reservoir to processing stations. During drilling operations natural gas, silica and heavy materials generate health hazards too.

The methods followed in rig site is also one of the reasons for risks. The operations are carried out in elevated heights and chances of slip and fall are common. The oil companies are very strict on their policies regarding Health Safety Environment (HSE) regulations and its implementation at rig site. Wearing low quality Personal Protective Equipment's (PPE) also invite health hazards.

Human errors are also common at rig site, especially slips due to water or oil on the rig floor. The lack of proper guard rails, improper ladder usage increases the risk possibilities. The companies are trying to implement safety nets and personal fall arrest systems to avoid accidents. The oil rig processes demand lifting heavy items, bending, reaching over head, pushing and pulling heavy loads, working in awkward body postures etc. Most of the oil rig operations are similar tasks and are executed repeatedly. This demands awkward postures, back bending, high arm postures, vibrations, contact stress and fatigue due to prolonged standing. The above-mentioned factors are the prime risk generators at rigs.

The rig operations are carried out at high-pressure conditions and demands spending of long period, mostly at remote locations. The cost of doing business at rig sites is very high. Even a minute delay against cost will generates work pressure on workers. The noise level of the working environment commonly increases stress hazards among workers. Most of the rig locations are remotely placed and demands long distance travel to and from the job sites. The shift systems practiced at rig sites demands 7–14 days availability with work schedule of 8–12 h. The flammable vapors released from well bores at the time of drilling may cause ignition and related hazards. The variations in parameters like temperature, light, wind and humidity can also affects the health of the workers and their performance. In addition, explosion possibilities are more in the rig site due to the sleeping habits, the quality of food available, duty-free tobacco etc. also initiates health hazards to the workers. Storage tanks and reserve pits around the well head also makes the working environment congested. The summary ergonomic risk identified, consequences and responsible person in oil rig for controlling this risk are listed in Table 1.

The risk issues reported from mud mixing unit is mainly depended on the posture followed by the worker. The worker must execute various manual material handling operations such as lifting and carrying along with movements are compulsory for job execution. The mixing hopper specifications also plays a role in deciding the posture of the worker to mix the mud. The workers' anthropometry and height of the hopper directly affects the body posture while performing the task. The HSE regulations are very strict in the industry, but the lack of training and monitoring makes the workers to sustain with the posture they followed for long years. The conventional rigs are still persistent in the world and automation is still in progression stage. This is one the factor that the workers must execute the operations manually rather that with mechanical support systems. The formation properties have key influence in frequency of mixing and transport of mud from storage places. The study shows the standardized approach that has to be practiced for keeping the concerns of workers.

Table 1 Summary of risk identified in oil rigs

Sl. No	Risk identified	Impact	Consequences	Responsible person
1	Drilling machinery	Worker performance	Chances of lifting heavy weights	Rig move coordinator
2	Work from height	Safety of workers	Falling from heights	Drilling supervisor
3	Drill pipes insert and removal from well bore	Injuries	Hand and feet wounds	Driller
4	Supporting Equipments like cranes and forklifts	Unstable loads	Accidents can cause broken bones	HSE officer
5	Use of hazardous chemicals	Flammable hazards	Burns, ingestion of poisons, expose to toxic fumes	Rig manager
6	Use of low-quality PPE's	Worker performance	Health of the worker	HSE officer
7	Slips due to water and oil	Safety of workers	Injuries to workers	Floor hand
8	Awkward postures	MSD's	Absenteeism	HSE advisor
9	Remote locations and shift schedules	Worker performance	Mental health problems	Shift supervisor
10	Vibration	Worker health conditions	Hearing impairment	Toolpusher

4 Conclusion

The fishbone diagram or cause-effect diagram act as an efficient risk assessment tool for assessing risk prevailing in oil rigs. The methodology followed in identifying risk factors provides an awareness on possible factors which affects the performance of the rig. The oil and gas companies use this analysis as a planning tool to increase their productivity. They address the identified factors through brainstorming sessions among managers and comes out with mitigation plans. The risk factors in mud mixing operations are mainly due to direct contact with chemicals repeatedly. The facility layout planning at rig sites plays a critical role on deciding the movements of the mixing operators. The poor layout creates unnecessary movements to the workers and affects their efficiency. Though there are strict HSE regulations to be followed at industry, the workers show hesitation in following them. A proper well planning and adherence to the HSE regulations can reduce the risk levels at oil rigs to a large extent.

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The Revival of the Tribal Community by the Concept of S.M.A.R.T. Village: A Case of the Sabar Tribe of Jharkhand, India

Nazish Abid, Mohd. Resaal Ansari, and Mazharul Haque

Abstract Majority of tribes in India are in a fragile state of dilapidation. Some of these tribes are categorized as primitive tribal groups owing to their meager socioeconomic status among other sociological factors. Sabar is no exception to this—mainly dwelling in Jharkhand, Chattisgarh and West Bengal. The community lives along the lines of a traditional primitive lifestyle, mainly dependent on forest resources—creating a lack of basic amenities such as shelter, sanitation & water supply. On the other hand, Sabars are proficient craftsmen—specializing in brooms, baskets, ropes etc. However, a lack of adaptation of these products to the current market leaves the craft with relics that cannot be sold at their required value. The Sabar craftsmanship is on the verge of extinction—the promotion of such tribal ethnic groups will not only restore the lost art, but will also increase the nation's GDP and in turn the global ethnic affairs. This document discusses how to adapt to the development of self-sufficient community solutions-providing them with reasonably priced & sustainable basic amenities, with the final goal to improve the community's living standards.

Keywords Tribal communities · Fragile and dilapidated · Skilled artisans · Primitive · Self-sufficient community · Sabar Tribe

1 Introduction

India is known to be a greatly diverse nation consisting of a variety of ethnicities and cultures. This variety includes many tribes or adivasis viz. Bhil, Andh, Chechwar, Gond Kammara etc, living in varied parts of the country.

Some of these tribes are categorized under primitive tribes due to their socioeconomic state in conjunction with other sociological factors of remote living and lack of access to resources and necessities. The people of this category live in run down houses and depend on unreliable forest produce for nourishment. A majority

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of these tribes are proficient craftsmen who are skilled in producing wooden toys, statues, bamboo sculptures, clay ornaments and paintings among many others. Due do a drop in value for their crafts, these craftsmen are forced to leave their art and join the minimum wage workforce—leaving them on the verge of extinction while endangering their cultural identity. Although an attempt at intervention has been made by the government and some non-governmental organizations, these have not created the required effect.

2 Aim and Objectives

2.1 Aim

Improving the lifestyle of the primitive Sabar tribe through a sustainable, holistic approach intended to improve their living and working conditions through the provision of basic facilities.

2.2 Objectives

1. Research the Sabar tribe's current living and working conditions.
2. To investigate the state of their arts and crafts.
3. To develop ways to strengthen infrastructure and basic human needs such as housing, health, and education.
4. To find ways to develop and promote the community's arts and crafts.
5. Investigate different models and tools for putting the proposed solutions into action.

3 Tribes and Primitive Groups of India

The scheduled tribe (ST) population is 104.2 million, accounting for 8.6% of India's total population [1]. ST communities are concentrated in Madhya Pradesh, Maharashtra, Orissa, Gujarat, Rajasthan, Jharkhand, Chhattisgarh, Andhra Pradesh, West Bengal, and Karnataka. The ST population is dispersed throughout the world, displaying a diverse culture and socioeconomic status. According to the notified Schedule under Article 342 of the Indian Constitution, there are approximately 700 tribes (with overlapping categories in some States/UTs) [2]. Primitive Tribal Groups (PTGs) are around 75 such groups found in 17 states and one territory. The majority of these communities are small in size and live-in rural areas with little facilities and administrative support. Many of them are socioeconomically disadvantaged and have not reaped the benefits of construction programmes or other initiatives [3].

4 Sabar Tribe

The Sabars are a PTG found primarily in Jharkhand's Singhbhum district, West Bengal's Midnapur and Bankura districts, and Orissa's Keonjhar and Dhenkanal districts. Basketry, collection of minor forest produce, lac cultivation, and agriculture are the main economic activities of Sabars [4]. The Sabar tribe is mentioned in the Hindu epic Mahabharata [5], was labelled a criminal tribe under colonial rule, and continues to bear the stigma of criminality. From any perspective, their abuse and exclusion are visible [6].

5 Arts and Crafts of Sabar Tribe

The Sabars have relied on making products out of bamboo, palm leaves, and Kanshi grass, which are abundant locally, for many generations. They make a small number of pieces, such as brooms, ropes, and baskets, and sell them in nearby markets or Haats. Despite being professional craftsmen, demand for their goods and capability was poor, and they could never command a fair price, putting the PTG's craft on the verge of extinction. Crafts have also declined due to a lack of promotion and access to major markets [7].

6 Issues and Challenges of Sabar Tribe

Following their traditional, primordial lifestyle, these primitive tribes are completely dearth of basic services, resulting in utmost poverty & malnutrition. Many of the community are forced to survive on a maximum of 30 g of food per person per day. PTG's literacy rate is very low (PTG only accounts for 1.73% of the state's tribal literacy rate, Sabar's 88% are illiterate, and other PTG's literacy rates are between 5 and 16%).

PTG is a Tribe that is in Danger Both Ecologically and Biologically. Their situation is dire with dwindling population numbers down as little as 100 per tribe. They are fighting for their lives with hurdles of starvation, illness and safety in natural disasters.

Living Conditions

6.1 Housing

The Sabar houses are twig, leaf, and stick huts that aren't tall enough for an individual to stand in [8]. Some members already have housing facilities due to the Birsa Awas

Yojana scheme. However, there are no toilets within the buildings—leaving bathing and toilet activities to the fields and waterfalls.

6.2 Remote and Inaccessible Habitats

These villages are in inward and remote areas and require a long travelling distance.

6.3 Electricity

Approximately 90% of the community members do not have a connection. Even so, those that do almost never have an active supply of electricity.

6.4 State of Economy

Their economy was almost entirely dependent on Arts and Crafts. However, the current state of affairs leaves the tribes people mainly involved in labour and construction. Some people make a living selling timber cut from the forest, with a monthly income ranging from Rs 500 to Rs 1000 [8].

6.5 Left Wing Extremism

Many of the easily accessible tribes are in areas dominated by left-wing extremism. However, other tribal villages are scattered throughout the country.

7 Need of the Project

As mentioned earlier, the Sabar tribe although greatly skilled artisans, are currently being forced to leave their honed crafts to work minimum wage jobs. This has lead to a displacement and separation from their roots and tribal community- creating a growing loss in identity, culture and craft as well as the tribe itself. All this put together, leaves the Sabar Tribe in an insecure state of affairs, due to a shortage of basic amenities.

Thus, with the interest of uplifting this community and its craft, the lives of its members must be improved in terms of both living and economic conditions. This

may be done in a variety of ways including the revival of dying crafts, provision of basic facilities in a long-term and financially approachable manner.

7.1 Provision of Housing, Life and Livelihood

Housing is one of the main requirements of the Sabars. The current conditions indicate houses with minimal facilities. Thus, planned, and intentional housing is necessary to provide amenities like toilets, electricity and sanitation facilities—while still inculcating and representing their cultural traditions. This research aims to be well rounded and look at avenues to better the lives and work acumen of the community members. One way of doing so is to establish a common workshop or training center to house the practice and perfection of craft knowledge. It will also act as a platform for the exchange of knowledge, sales in the local market and the inculcation of an e-commerce engine. The goal is to enforce accommodation and income in their existing location to lead to a better life.

8 S.W.O.T. Analysis

See Fig. 1.

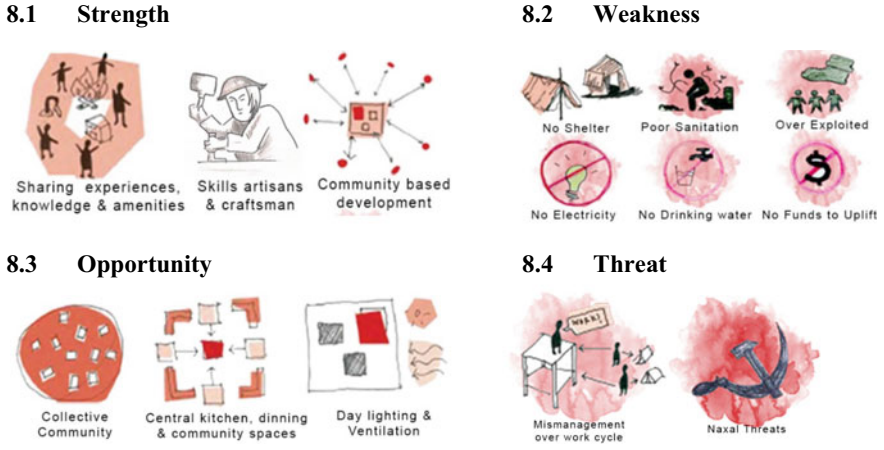

Fig. 1 SWOT analysis. *Source* Author

9 Project Proposal

9.1 "Sanrachna" and "Sahbhagita"

The words "Sanrachna" and "Sahbhagita" mean "creation" and "participation," respectively. The people of the Sabar tribe have a strong connection and sense of belonging to their tribe and one another. Sanrachna and Sahbhagita, which aims to build better infrastructure and living standards for the Sabar tribe, will also allow them to participate in all stages of the project—creating the same sense of belonging and participation in a new sense.

9.2 S.M.A.R.T. Village Concept—What and Why?

This concept aims to inculcate all these factors to design and build a village for the Sabar tribe—allowing for profitability to both the tribe members and investors. To achieve this, the project will involve the use of local materials in conjunction with sustainable & renewable energy and water sources. The concept also pays attention to the promotion of the Sabar's artisans and craftsmanship through the implementation of a studio for the village—later allowing for a sales and e-commerce platform to reach both local and global markets. Using the S.M.A.R.T. ideation, the village and tribe will not only excel but also solve the issues of housing, education & livelihood.

10 Site Location

See Table 1.

Table 1 Project location and accessibility

Site location			
Village:	Kalapathar Chakri, Chakulia	Nearest Town:	Chakulia (15 kms)
District:	East Singhbhum, Jharkhand	Nearest Village:	Khayalbani, Bend
Population:	Males: 72	Connectivity:	Roadways
	Females: 83		Public Transport
	Children (0–6): 24		

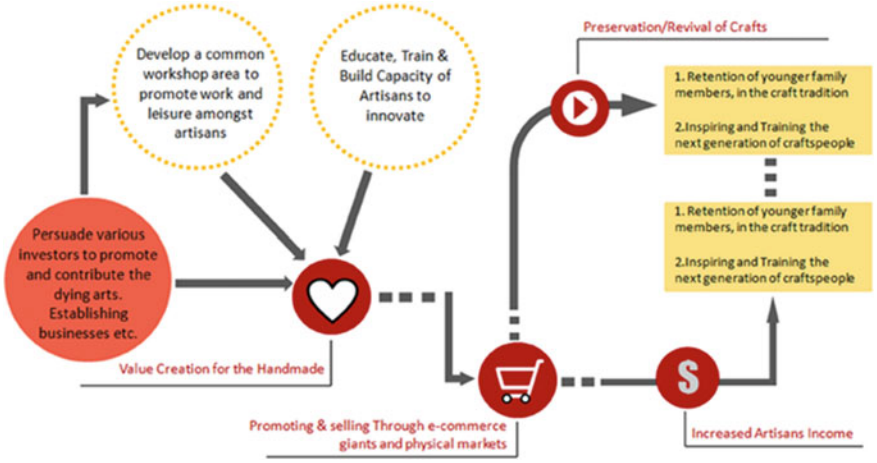

Fig. 2 Administrative level strategies. *Source* Author

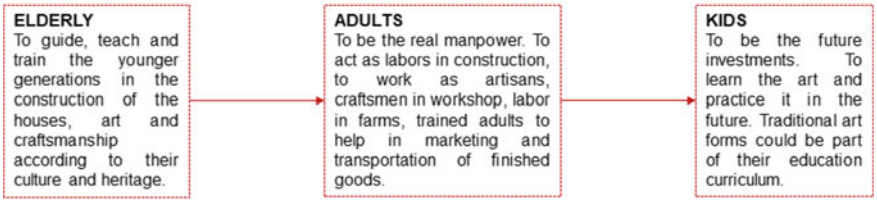

Fig. 3 Hierarchy of craftsmanship. *Source* Author

11 Strategies

11.1 Administrative Level

To propose the implementation of a training center in affiliation with marketing giants and e-commerce. This will promote broadening the market and target audience of the products—allowing them to be sold at a higher and more comparable value while also leaving way to update their designs (Fig. 2).

11.2 Carrying Out the Legacy

The tribe's various generations will collaborate and practice their art while carrying on the tribe's legacy, as it was practiced in the past (Fig. 3).

11.3 Supporting Element

Proposing the affiliation of various bodies will be integral in the village's process of development and maintenance. (1) **Central and state governments**: to release funds and track them. (2) **Local government**: local authority involved in controlling and distributing the funds gained from the federal government. (3) **Non-governmental organizations (NGOs)**: will assist with outreach programs, volunteers and innovation. (4) **Educational Institutions (SPA, NID, NIFT, IIT, and others)**: Educators and students can volunteer/be advised to assist in the development and improvement of goods and products. (5) **MNCs and companies operating in the field of sustainability**: can act as integral assistance to the supply, installation and execution of new and innovative technology at a fair price. (6) **Public participation**: Most crucial aspect of the project is always the tribe's participation.

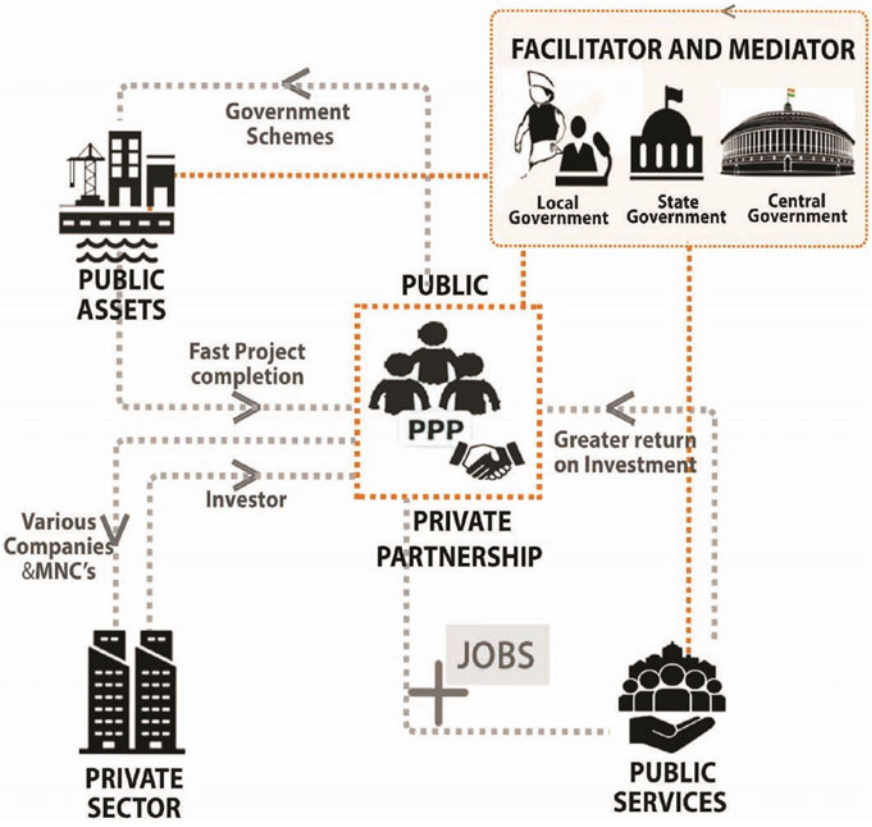

Fig. 4 Implementation models and tools. *Source* Author

12 Models and Tools of Implementation

See Fig. 4.

12.1 Public Private Partnership Model

An already established concept, a public–private partnership (PPP) is an agreement between a government agency of one party and a private sector entity of the other party to provide public assets and/or services to private sector entities through financing and/or management by a fixed period of time [9].

In this scenario, the public sector, i.e. various government bodies (federal, state and local) will act as facilitators and mediators to the success of this project. Their roles will include the supervision and monitoring of the project development at various critical stages. On the other hand, the private sector will be a host of companies and multinational companies acting as investors and providers.

12.2 Public Participatory Planning

An established and successful tool, Participatory systems can design egalitarian and inclusive decision-making processes with the same material outcomes, helping to strengthen the power of the poor and the oppressed for the just distribution of material resources [10].

As mentioned earlier, a critical point of this project's implementation is the participation of both the tribe and other local public. This interaction with the project will allow for a more cohesive understanding of the Sabar's requirements, restrictions and problems being faced. Not to mention the careful implementation of the tribe's culture and viable vernacular techniques. This interaction would have to be observed across all community members, regardless of age, sex or other social demographics. With the involvement of the tribe, funding could be used to create jobs on site rather than serve outside labourers and construction workers.

13 Proposed Strategy Stellate

Several strategies at both micro as well as macro levels were carved out to address the issues and challenges faced by the tribe in their daily life. The strategies adopted address the short term as well as long term goals of the study and is derived for a holistic growth and development of the community focusing on various sectors in a sustainable manner (Fig. 5).

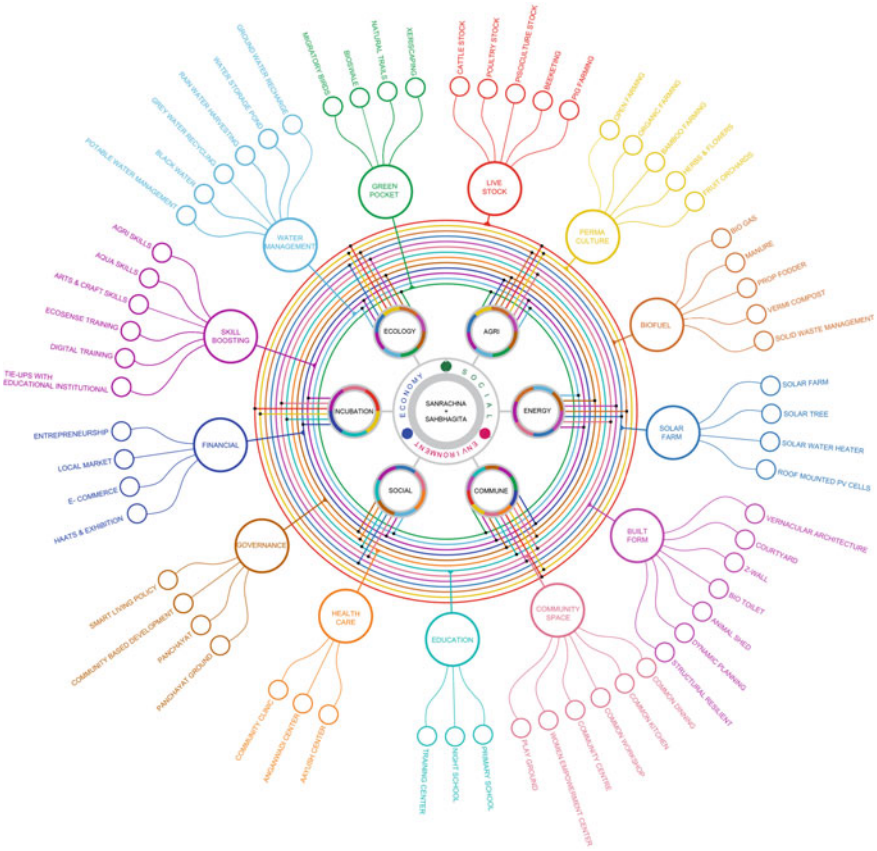

Fig. 5 Proposed strategy stellate. *Source* Author

14 Proposed Target Issues

The target issues are the adaptation of strategies to address the major issues, the community is facing, into physical spaces and studying its effect and impact on the people of the community physically, socially, environmentally and economically. The study helps in better adoption of strategies and creating better physical spaces for the community as per their needs and also addressing their issues (Fig. 6).

15 Proposal

Using the prior factors of observation and research in the current state of the Sabar tribe (challenges, living conditions, financial conditions etc.), several strategies,

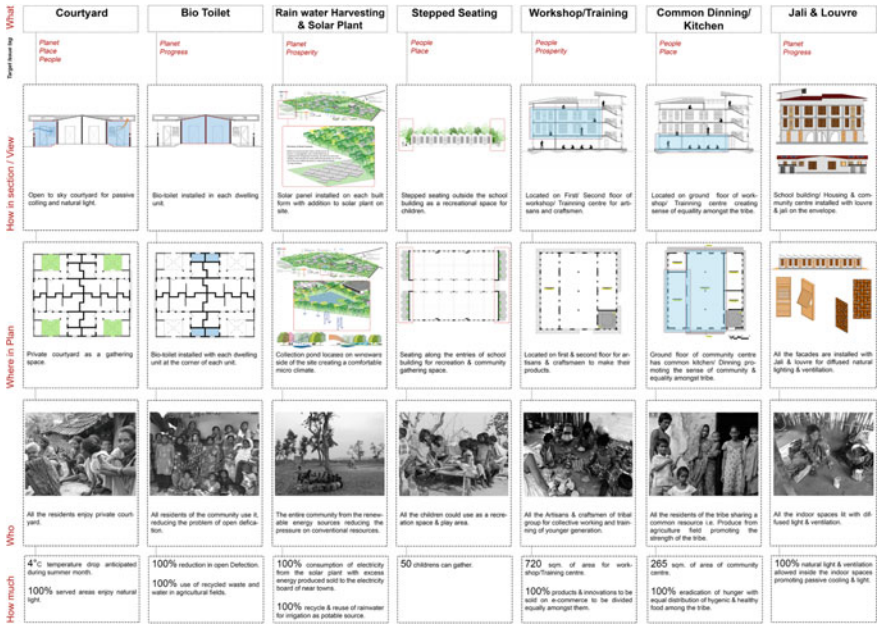

Fig. 6 Proposed target issues. *Source* Author

models and innovations were aligned to create a Model Village for this community. As shown in Fig. 7, these strategies outline fiscal, financial and other tools to aid this renovation & restoration. The Model Village aims to enhance the community's living and cultural facilities while maintaining and preserving their core. This is done by preserving the local flora and fauna while simultaneously implementing sustainable systems such as passive energy cooling systems and a rainwater harvesting system.

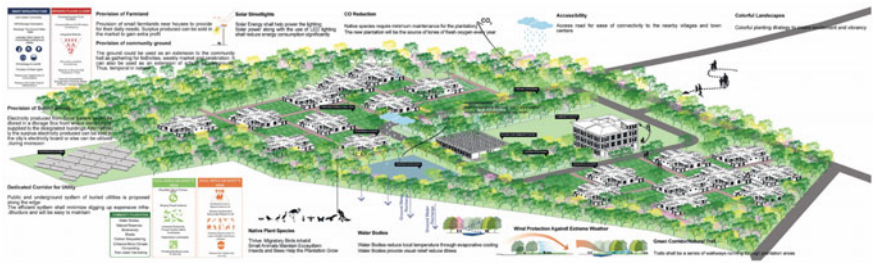

Fig. 7 Proposed model village. *Source* Author

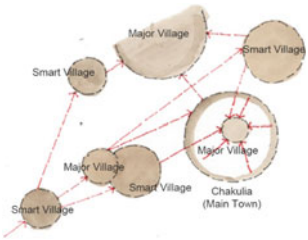

Fig. 8 Schematic diagram of the project phasing. *Source* Author

16 Proposed Phasing of the Project

Phase I: The production phase begins with the excavation of the pond; creating the material used to build CSEB bricks. This is followed by the construction of residential units comprised of CSEB bricks, bamboo frames and solar panelled thatched roofs.

Phase II: The next phase involves the development, construction, and opening operations of the village's public amenities such as the workshops, schools and medical facilities. This phase also implements resources such as roads and sanitation facilities.

Phase III: The final phase comprises of retrofitting the village's buildings to meet the new Smart Village norms. This means retrofitting existing village homes, schools and other buildings with fixtures such as solar panels, jaali job, compost toilets etc.

In order to ensure the smooth working of the newly implemented resources in the Village Model, the allocated number of houses to be built will not be exceeded. Instead, a new village may be built nearby with its own resource bank. This macro model would mean a series of satellite villages connected through one central village serving as the commercial and public hub with amenities such as banks, post offices and higher secondary schools (Fig. 8).

17 Contextual Application and Conclusion

This S.M.A.R.T. Village model will holistically restore the living conditions of the Sabar tribe with the provision of basic needs alongside special interventions to uplift the tribe's artisans and their craft. These interventions will allow for a more current world approach to artisans' skill sets and up gradation of prior designs—allowing for more cultural integrity and security in the craft in both a social and economical manner. With the inculcation of more educational facilities and vocational training, the increasing literacy rate of the tribe will in turn increase the nation's overall status through its GDP. The S.M.A.R.T. Village Model, once implemented in this scenario can be used as a model in any run-down part of the country and the world. Its ultimate aim is to provide shelter and nourishment to those who cannot access them- creating a goal that can be shared by many investors for the greater good of

the nation, subsequently removing the added requirement of government funding. Not to mention its clear strategies for the preservation and restoration of the nation's dissolving arts and crafts-Himachal Pradesh's ChambaRumal Painting and Bihar's Madhubani Sculpture to name a few. Overall, the S.M.A.R.T. Village Model aims to move the nation forward in its skill sets, implementation of technology and its diverse production possibilities—with the careful understanding and preservation of its root culture.

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Modifying the Revised NIOSH Lifting Equation in the Presence of Noise

Nadeem Ahmad, M. Muzammil, and Saman Ahmad

Abstract An Experimental research was conducted to modify the revised NIOSH lifting equation (RNLE) by determining the effect of various noise levels on recommended weight limit (RWL) during symmetric and asymmetric lifting. Seven male college students were recruited as participants. Each participant performed 16 different lifting tasks. Subjects were required to lift a box from the floor to a 76 cm high pallet for a period of 15 min. A psychophysical methodology was used to establish the acceptable lifting frequency for different combinations of load, asymmetry and noise levels. Oxygen consumption was also measured both at rest and immediately after the experiment. The observations gathered were analyzed using ANOVA, which showed a significant effect of all three variables viz load, asymmetry and noise on lifting frequency as well as oxygen consumption. RWLs were calculated using RNLE and it was observed that they decreased with increase in load, asymmetry and noise. On the basis of the experimental results a RNLE multiplier was suggested for load lifting in the presence of noise.

Keywords Noise · Load lifting · Revised NIOSH lifting equation · Recommended weight limit

1 Introduction

Despite increasing automation, manual mode of lifting remains indispensable, especially in situations where human beings are responsible for taking instant decisions depending on circumstances [1]. In developing countries like India there is an abundance of cheap manual labor. Further, in developing countries there is a dearth of governing body/controlled law to safeguard the interest of workers making them

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highly susceptible to work related musculoskeletal disorders and low back pain [2]. Injuries sustained due to manual lifting activities are one of the leading occupational health and safety issues faced by the industries. Manual material handling (MMH) and load lifting are major causes of work-related low back pains (LBP) and impairments [3–5].

In light of the growing problem of work-related back injuries, National Institute for Occupational Safety and Health (NIOSH) proposed a lifting equation (NLE) that aimed at controlling the risk associated with manual lifting, by recommending safe loads. The equation was later revised, in 1991, and came to be known as the revised NIOSH lifting equation (RNLE) [4, 6]. It is perhaps the most commonly used method to identify increased risk of back pain. It has been widely used as the basis of many manual lifting standards in European countries.

The RNLE takes into account factors related to the lifting task in order to arrive at the Recommended Weight Limit (RWL), which is believed to be safe for 90% of the working population. However, it does not consider the effect of environmental stressors like noise and high temperatures, to which workers are subjected to on a daily basis. High occupational noise exposure was reported in 17 studies conducted across 12 countries in South America, Africa and Asia [7, 8]. In the United States alone, about 9 million workers are exposed to Time-Weighted Average (TWA) sound levels of 85 dB(A) and above [8]. In the European Union, 28% of workers surveyed reported that they are occupationally exposed to noise in the range of 85–90 dB(A) at least one fourth of the time [8]. Noise levels in construction sites was found to range from 74 to 104 dB(A) [9]. Air jets, extensively used in manufacturing sector, may generate sound pressure levels of 105 dB(A) at a distance of 1 m from a blow-off nozzle [10]. In foundry cleaning rooms, noise has often been found to exceeds 110 dB(A) [9]. Equivalent sound pressure levels (Leq) in the furniture manufacturing industry can reach 106 dB(A) [10]. Pressure pulses from compressors may result in equivalent sound pressure levels of 105 dB(A) [10]. Noise levels of hand-held tools such as drills, grinders, riveting guns, chipping hammers, impact guns, pavement breakers, etc. can reach 110 dB(A) at the operator's ear [10]. Such high levels of noise are known to cause a physiological effect on workers thereby leading to reduced performance [9]. A study on the effect of noise on human performance indicated that it had a statistically significant effect on human performance [11]. It is important to note that the most commonly used tool for manual lifting, the RNLE, does not take environmental noise into account while deciding safe loads.

While a number of studies have been conducted on the role of noise on cognitive tasks, its effect on manual tasks performance is relatively unexplored. Further, since the effect of load lifting is multifactorial, long term implications of lifting under environmental stressors may be needed to control work related low back pain. The present study therefore attempts to investigate the effect of noise on lifting frequency and oxygen uptake, using a psychophysical approach. Oxygen uptake has been used as a criterion for establishing the safe load limits for the RNLE [4]. The effect of frequency on MAWL is well established. Higher the frequency, lower the MAWL. The RNLE also uses frequency of lift for the calculation of RWL. Fox and Smith have used a similar approach to study the effect of load on high frequency arm lifting

[12]. On the basis of this study, modifications in the revised NIOSH equations have also been recommended to incorporate the effect of noise.

2 Methodology

The study attempts to explore an individual's lifting performance in a noisy industrial environment. The effect of load, asymmetry and noise on a lifting task performance was investigated. The dependent variables chosen were oxygen uptake and frequency of lift. Experimental investigations in simulated and controlled environment were carried out at Ergonomic Research Division lab in the department of Mechanical Engineering, Aligarh Muslim University (AMU), Aligarh, UP, India.

Seven healthy male subjects were selected to perform the task. Before the starting of the experiment, participants were informed about the procedure and the possible risks involved in the experiment and their consent was obtained. Table 1, indicates characteristics of subjects associated in the experiment.

2.1 Experimental Procedure

The effect of lifting frequency on manual lifting is well established. As per the RNLE, increase in frequency of lift results in a decrease in MAWL. This effect of frequency on the three independent parameters namely load, asymmetry and noise were investigated in the present study using a psychophysical methodology. However, in relation to most other psychophysical studies on lifting, the subjects in this study were asked to adjust the frequency of lift until it represented the maximum frequency that the subjects could sustain for given weight for an 8-h work day. The initial frequency was anywhere between 2 and 6. The start of a lift was indicated by a buzzer. The subjects were then asked to increase or decrease the frequency after every 3 lifts. The experimenter changed the frequency by 2 lifts per minute, unless the subject asked for a small increase/decrease, in which case a change of 1 lift/minute was done. A similar methodology has been used by Fox and Smith [12].

Since psychophysical studies generally involve changing loads, A pilot experiment was conducted to establish the task duration. It was found that most subjects arrived at the acceptable frequency in the first 10 min of the task. Thus, the task involved lifting a rectangular box located at ground level to a 76 cm high platform

Table 1 Characteristic of subjects participated in study (N = 7)

Characteristics	Mean	Std. Deviation (SD)	Range
Age (yrs)	23.9	3.07	20–29
Weight (kg)	62	9.53	48–60
Height (cm)	172.47	5.41	165.1–180.34

for a period of fifteen minutes without interruption. Lifting of the rectangular box was carried out using both hands. The average frequency of lift (F) during the last 5 min was recorded as the acceptable frequency. Subjects were required to lift a load from four different origins of lift viz. a sagitally-symmetrical origin (A = 0°) and three asymmetric origins (A = 30°, 60° and 90°) and place them at a sagitally-symmetric destination. 4 noise levels i.e., ambient (60 to 70 dB(A)), 80 dB(A), 85 dB(A) & 90 dB(A) and 3 levels of load viz. 10, 12 and 15 kg were also investigated. The noisy industrial environment was created with the help of audio tape recorder and speakers. The required level of noise was measured using a sound level meter. All experiments were conducted at a room temperature over a period of 2–2.5 months.

Various parameters like horizontal distance of load (H) located at origin and destination and vertical height of lift (V) were measured. Frequency of lift at various levels of noise, loads and asymmetries was used to calculate the corresponding Recommended Weight Limits (RWL) using the RNLE. Further, taking RWL values at ambient noise levels, for a given set of load and asymmetry condition, as the baseline, difference between the RWL at ambient conditions and different levels of noise were obtained. These were then used to calculate the multipliers for modification of the RNLE.

Oxygen consumption was used as a physiological measure to assess the metabolic stress induced by the lifting task. It was measured with the help of a portable tank type spirometer (Range: 0 to 6000 cc, Least count: 50 cc). Three sets (03) of reading, at intervals of 1 min, were taken for each subject(s) before and instantly after completion of experiment. The difference between average of the readings at rest and after the experiment was taken as a measure of the metabolic load of a task. The entire set of experiments were carried out by all seven participants (Fig. 1).

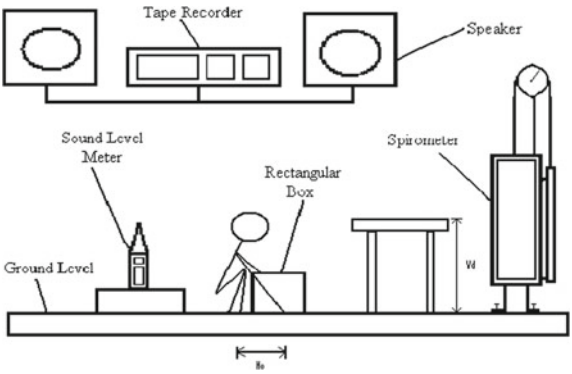


Fig. 1 Experimental set up

3 Results and Discussion

Maximum frequency of lift and oxygen uptake at rest and immediately after completion of the experiment were gathered for all combinations of load, asymmetry and noise. ANOVA was carried out for the observations gathered. Results obtained are presented in Tables 2 and 3.

As evident from the Table 2, all three independent factors namely load, asymmetry and noise had a statistically significant effect on frequency of lift. All two way and three-way interactions however, were statistically non-significant.

ANOVA performed on the change in oxygen uptake with changes in levels of load, asymmetry and noise revealed a statistically significant effect all three parameters on the lifting task. The findings corroborate the results obtained by the psychophysical studies. The results are shown in Table 3.

Table 2 ANOVA results forthe effect of load, asymmetry and noise on frequency of lift

Tests of between-subjects effects					
Dependent variable: frequency					
Source	Type III sum of squares	df	Mean square	F	Sig
Load	9.965	2	4.982	30.856	0.000
Noise	12.200	3	4.067	25.185	0.000
Asymmetry	51.104	3	17.035	105.492	0.000
Load * Noise	0.392	6	0.065	0.404	0.876
Load * Asymmetry	0.343	6	0.057	0.354	0.907
Noise * Asymmetry	0.220	9	0.024	0.151	0.998
Load * Noise * Asymmetry	0.203	18	0.011	0.070	1.000

Table 3 ANOVA results for the effect of load, asymmetry and noise on oxygen uptake

Tests of between-subjects effects					
Dependent variable: VO2_change					
Source	Type III sum of squares	df	Mean square	F	Sig
Load	77,107.661	2	38,553.831	211.026	0.000
Noise	17,119.759	3	5706.586	31.235	0.000
Asymmetry	12,896.958	3	4298.986	23.531	0.000
Load * Noise	1326.688	6	221.115	1.210	0.301
Load * Asymmetry	1148.518	6	191.420	1.048	0.395
Noise * Asymmetry	724.192	9	80.466	0.440	0.912
Load * Noise * Asymmetry	4234.500	18	235.250	1.288	0.194

Results of the present study indicate that with increase in load, the frequency of lift decreased, as did the RWL obtained from the RNLE. It is also important to note that despite the lower frequencies and RWLs, change in oxygen uptake increased. This indicates increased metabolic stress with increase in load, despite the decreased frequencies (Fig. 2).

Results of the present study indicated that as the asymmetry increased, frequency decreased. When RWL was calculated using the RNLE, it was found that despite the decrease in frequency, RWL decreased and change in oxygen uptake increased. Also, as reported by several researchers, the change in RWL with increase in frequency did not follow a linear pattern [11, 13, 14]. It was noted that the RWL decreased at a lower rate as the asymmetry increased. This however is contradictory to earlier results that generally reported that as asymmetry increased, MAWL decreases as a faster rate [15, 16]. The apparent contradiction may be because instead of MAWL, in the present study, maximum acceptable frequencies have been taken as the dependent measure. The RWL has then been calculated using RNLE. Thus, the effect of asymmetry has already been taken into account by the equation. Yet, a decline in the RWLs is observed (Fig. 3). The fact that the RWLs calculated decreased despite lower frequencies may point towards the need to modify the asymmetry multiplier. Similar findings have been reported by Kee and Chung and Swei Pi (2000 and 2003) [13, 17, 18].

Noise was found to have a statistically significant effect on the frequency of lift. As noise levels increased, frequency of lift decreased. RWL was calculated using the RNLE for all levels of noise. As expected, the lower values of frequency resulted in higher RWLs. Taking the RWL at ambient noise levels as the baseline, change in RWL with change in noise levels was calculated. It was seen that change in oxygen uptake increased with increase in noise, despite lower frequencies, as shown in Fig. 4. It was also noted that as with load and asymmetry, lifting frequency decreased with increase in noise levels, as shown in Fig. 4. It was observed that the percentage change of RWL, w.r.t RWL at ambient noise levels, increases with increase in noise levels as shown in Fig. 7. This clearly indicates a need for a multiplier for noise to safeguard workers performing manual handling tasks (Figs. 5 and 6).

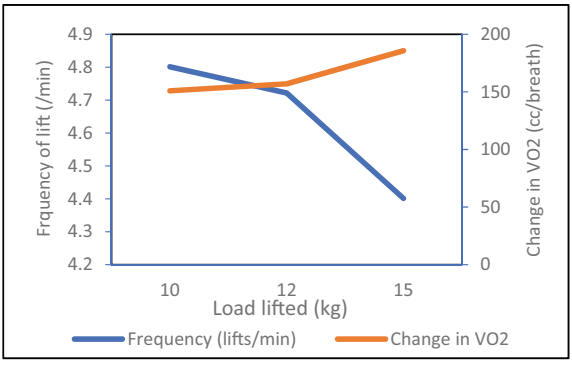


Fig. 2 Effect of load on lifting frequency and change in VO2

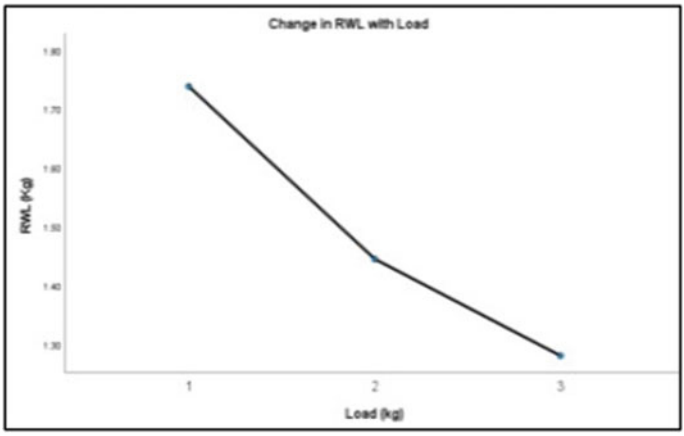
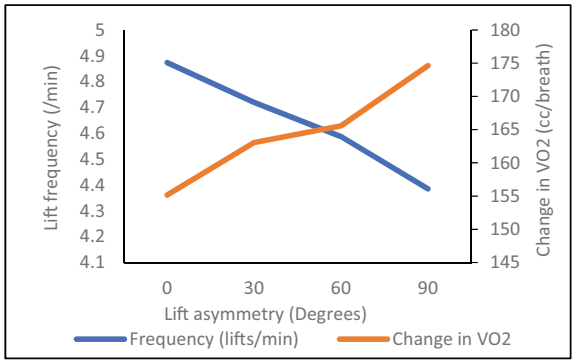


Fig. 3 Effect of load on recommended weight limit of RNLE

Fig. 4 Effect of lift asymmetry on frequency of lift and change in VO2



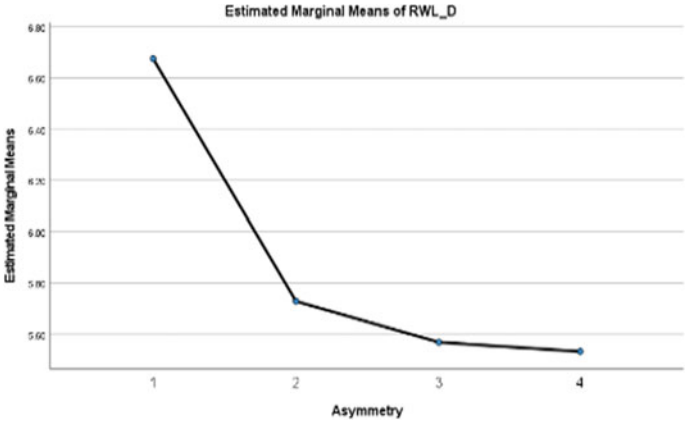


Fig. 5 Effect of Asymmetry on recommended weight limit of RNLE

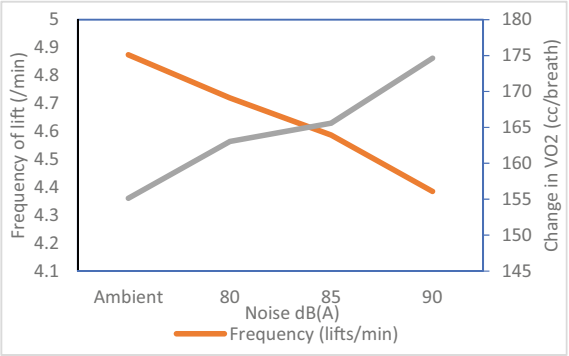


Fig. 6 Effect of noise on oxygen uptake and frequency of lift

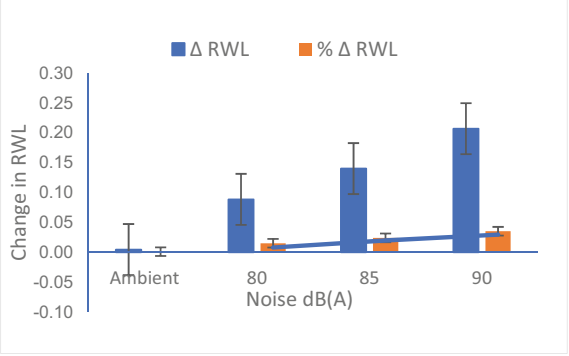


Fig. 7 Effect of noise on change in RWL

While the effect of asymmetry and load has been accounted for in the RNLE, noise has not been given due consideration while deciding the safe load limits. Hence a multiplier to account for noise levels is perhaps needed. The MAWL obtained using RNLE in ambient noise was taken as the baseline. A ratio of the MAWL in noise and at ambient noise conditions resulted in the following multipliers (Fig. 8 and Table 4).

A graph of the percentage change in RWL with increase in noise showed a straight line. From the graph, it appears that the effect of noise on change in RWL follows a straight line with the equation. On the basis of the observations of the study, Eq. (1) for noise multiplier was recommended:

$$y = 1.1513 - 0.002x \tag{1}$$

where, $y =$ Noise multiplier.

$x =$ Noise level.

While on the basis of the results of the present study it appears that the noise multiplier follows a straight line, and the graph may be extrapolated to higher noise levels, extrapolation of the said equation needs caution, as noise levels of only up to 90 dB(A) have been investigated. Since industrial workers are often exposed to

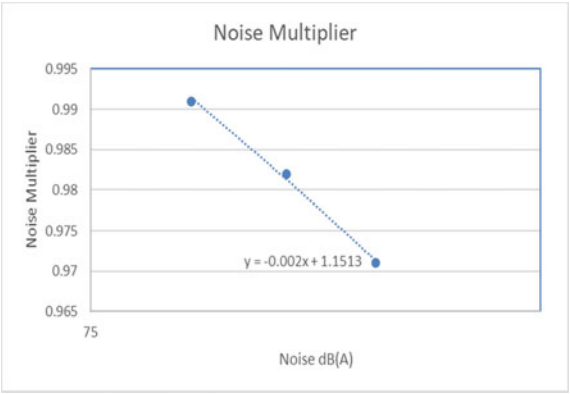


Fig. 8 Graphical representation of variation of noise multiplier

Table 4 Noise multiplier corresponding to noise level

Level of noise	Noise multiplier
80 dB(A)	0.991
85 dB(A)	0.982
90 dB(A)	0.971

much higher noise levels, more experiments may be required to establish the exact relationship between RWL and noise and to suggest multipliers for higher noise levels.

4 Conclusions

It was observed that load, asymmetry and noise had a significant effect on frequency of lift and oxygen consumption. It was also noted that despite reduced frequencies with increased loads, asymmetry and noise levels, oxygen consumption increased. On the basis of the results, it appears that the asymmetry multiplier also needs to be revised. It was also concluded that safe limits in lifting tasks need to be modified in the presence of noise.

On the basis of the results obtained, a noise multiplier, in the form of an equation, was recommended for the RNLE. While at first glance it appears that the noise multiplier would follow a straight-line pattern, further investigations, at higher noise levels, need to be conducted before arriving at definite results. Also, while the recommended noise multipliers seem fairly minor, the testing has been done for only up to 90 dB(A). It is likely that the effect of noise at higher levels may be even more severe at higher noise levels, which are not uncommon in actual industrial environments. Therefore, further investigations are required at higher noise levels to get the complete picture.

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Development of Risk Assessment System for Sewing Machine Operators

Aastha Arora and Manoj Tiwari

Abstract The prevalence of Work-related Musculoskeletal Disorder in the Ready-Made Garment (RMG) industry is quite common. Due to repetitive actions and subsequent awkward postures, the sewing machine operators are prone to the risk of Work-related Musculoskeletal Disorders—WMSDs, which results in temporary or permanent disability among the operators. The study aimed to develop a Risk Assessment System that identifies the level of risk factors involved and eventually computing the Rapid Upper Limb Assessment (RULA) score of each operator. The discrete posture evaluation of the sewing operators was done by tracking the body joints of the operators using their videos while per-forming the tasks. Several socio-demographic, psychological, and work-related details were also factored in through a structured questionnaire for testing and validation. In total 72 videos recorded from either side of different sewing operators, were analyzed at the speed of 30 frames per second. A system was successfully developed by applying various machine learning algorithms to compute the RULA score by extracting the different joint angles of the operators like Neck, Upper and Lower Arm & Trunk directly from the video captured. Such a Risk Assessment System developed shall help in understanding the work conditions operators work in and eventually guide in reducing the risk of WMSDs through precautionary measures against the risk. Other benefits may include productivity enhancement, improving overall health, and reducing the rate of absenteeism, which continues to be a major concern among the factory owners and the Ready-made garment industry, in general.

Keywords Work-related musculoskeletal disorder · Ready-made garment industry · Motion tracking · Rapid upper limb assessment · Machine learning

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1 Introduction

With the abundance of favorable conditions like raw material availability, skilled workforce, technical know-how, and worldwide robust demand, India is on its way to becoming the leading textile & clothing manufacturer and exporter. In the near future, the demand for the textile and garment industry is bound to see an even higher rise—majorly driven by highly favorable demographics, increase in penetration of organized retail, and rising income levels. The increase in demand will surely boost up the employment in this sector. As of 2019, the Indian ready-made garment industry employed over 45 million people and according to the projected statistics, a total of 3 million new job opportunities will be created by the start of the year 2022 [1]. Now more than ever, it is extremely important to take into account the physical health and the subsequent ramifications of the increasing number of employees. It is a well-known fact that the garment industry—anywhere in the world, involves long working hours and monotonous repetitive tasks to meet tight delivery deadlines of the apparel orders. These factors along with awkward working postures of the operators cause a lot of physical stress and strain to the operators, ultimately resulting in various repetitive stress injuries like but not limited to Cubital Tunnel Syndrome, Carpal Tunnel Syndrome, Lateral Epicondylitis, Sciatica, Tendinitis, Medial Epicondylitis, Musculoskeletal Disorder, etc. A significant association between physical exertion at work and Work-related Musculoskeletal Disorders (WMSDs) has been demonstrated in many epidemiological studies [2]. Work-related Musculoskeletal Disorder (WMSD) is a broad term that refers to a variety of musculoskeletal injuries and disorders. It may strike abruptly or develop gradually [3]. The severity of MSD cases is higher than an average nonfatal injury or illness. Workers employed in a wide array of industries, such as transportation, textile and garment production, manufacturing, agriculture, and construction, are exposed and vulnerable to awkward postures, overextensions, intense exertions, and monotonous or repetitive actions for extended periods [4].

MSDs accounted for an average of 8 days off work in 2001, compared to 6 days for all nonfatal accident and sickness cases (e.g., hearing loss, occupational skin diseases such as contact eczema, contact urticaria, rash, or dermatitis) [5]. Employers face high expenses due to absenteeism, reduced productivity, and elevated health insurance costs, injury, and worker's compensation costs due to musculoskeletal disorders. W-MSD cases account for about 33% of total workplace injury cases, according to the US Bureau of Labour Statistics, making it the leading cause of lost productivity [6]. The prevalence of Musculoskeletal Disorder in the garment industry is quite significant. In May 2013, musculoskeletal complications were found to be present in 77.6% of the operators out of a sample size of 295 operators. This study was conducted at a garment factory in Tirupur, India. The most commonly affected regions were the neck (32.1%), knee (28.7%), and lower back (26.6%) [7]. In a study conducted in Kandal Province, Cambodia, at various medium-sized garment factories, in the last 7 days and last 12 months, 89% (Confidence Interval 95% = 86.7–91.3) and 92.0% (Confidence Index 95% = 90.0–94.0) of the participants registered musculoskeletal symptoms in at least one body area, respectively, out of a total of

10634 individuals [8]. According to a study conducted in Bangalore, ergonomic factors were responsible for 71.9% of musculoskeletal pain [9]. Researchers have previously investigated the relationship between demographic variables and MSDs among various workers [10–12]. Apart from the parameters of the working condition and workplace design, age, gender, smoking habit, alcohol consumption, and its frequency, dietary preferences, among other things, too are factors that contribute to the diagnosis of musculoskeletal pain [13].

To avoid WMSDs, it is necessary to identify the causative variables and take preventative actions to eradicate them. This will result in lower productivity and lower work quality [14]. The risk of occurring Musculoskeletal Disorders in the workplace may not be completely avoided, but with the help of better infrastructure and certain preventative measures like focus on better workplace design and improved health and safety training, the risk of Musculoskeletal Disorder can be drastically reduced as proven in various previous studies [9]. To assess the severity and intensity of the Musculoskeletal Disorders among the garment industry operators, it is pertinent to take into account their body posture. Quick Exposure Check (QEC), The NIOSH Lifting Equation (NIOSH), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and others are some of the most popular methods to study and analyze the body postures of the workers [15]. The Rapid Upper Limb Assessment (RULA) is by far the most widely used tool for sewing machine operator posture analysis since it allows to evaluate the upper limb disabilities that are most common among sewing machine operators as established earlier in this paper [16].

The RULA is an instrument for assessing postural ergonomic risk factors or biomechanical factors in the workplace by direct observation. RULA was under-taken in the garment manufacturing industry through the evaluation of operators who performed tasks such as cutting, using a variety of sewing machines, clip-ping, and inspection operations, among many others [17]. The regions of the body are scored in terms of body posture, external load/force, motion, and muscle function using this assessment technique. For example, if the lower arm is in the range of 60° extension to 100° flexion, the score will be 1, while if the load is equal to 2 kg or less and maintained intermittently, the force/load score will be taken as 0; whereas the muscle score will be 1 if an action is performed four times per minute or more, otherwise 0 [8]. This assessment technique is divided into three segments. Part A deals with the posture score of the upper & lower arm, the wrist, its twist and muscle, and the force/load score. After tallying all these details, the *'Arm and Wrist Score'* is computed. Similarly, Part B deals with the score of the trunk, neck, and legs analysis along with the force/load and muscle parameters. The result from this part is known as the *'Neck, Trunk and Leg Score'*. On comparing these two scores, Part C gives out the final RULA score of a subject and gives out class actions. The score ranges from 1 to 7 and each score defines the action class range and its subsequent interpretation [17]. While this technique has stood against the test of time and proved it worth, the one limitation of this technique is the long manual process of recording the data and then tallying to get the results. In the age of supercomputers and advanced machine learning, it is time that the garment industry, too, reaps the benefits of artificial technology and deep learning techniques. In a study completed in the year 2019, it was

discovered that by implementing advanced machine learning algorithms, the RULA score can be easily computed in a much shorter time while maintaining high accuracy.

With the assistance of a deep neural network, the researchers developed an advanced machine learning model for estimating RULA scores from real-time 2-D model poses [18]. As established earlier, for calculating the RULA score of any subject, the basic necessity is the range of the body joint angles or its exact value, i.e. the angles of lower & upper arms, neck, trunk, wrist, and legs. With the new age of technology, it is now possible to track the body joints of any subject and understand its movement pattern and even predict its next steps. With the application of various image processing techniques, it is possible to easily track the body movement and ex-tract the required angles, captured by a simple video camera [19].

For tracking of the body joint angles, there are two tried and tested approaches, first is the more conventional one, the *Marker-based* Technique and the other is the *Marker-less* technique. As the name suggests, the prerequisite with Marker-based techniques is the usage of fiducial/physical markers to track the body joints of any subject/object of interest in their working environment [20]. While the Marker-less technique doesn't require this prerequisite and helps to track the body joint angles of the subject in an environment free of the physical markers. With the help of object-based computer recognition, this approach is much more industry-oriented and applicable in real-world scenarios without changing the environment of the subject and disturbing the operator [21].

As confirmed in a research work conducted in 2014, by the application of deep learning methods, it is possible to do the complete human pose estimation to determine the body joint angles. The input is fed as the 2D RGB images from the marker-less capturing and as an output, 2D joint coordinates are produced, utilizing the joint centers of the human body [22]. One of the most famous and accurate algorithms that work on 2D, and 3D human pose estimation is the OpenPose algorithm. It is a cutting-edge, open-source pose estimation approach, it is mostly applied in the research of biomedical sciences [23].

This research discusses the development of a Risk Assessment System for the sewing machine operators of the ready-made garment industry, ultimately calculating the RULA score using the marker-less technique and OpenPose algorithm. This article is divided into 5 major sections, with this section as an introduction. Section 2 gives an account of the data collection process. In Sect. 3, an overview of the proposed methodology is presented. In Sect. 4 of this paper, the findings and discussions are outlined. Conclusion and possible future research is discussed in Sect. 5.

2 Data Collection

Preliminary research was carried out to determine the criteria for examining the prevalence of Musculoskeletal Disorder among sewing machine operators of the ready-made garment industry. The data was then collected from a garment factory in Gurugram, India in February 2021. Consent to perform the study during that period

was received from both the organization and the participants. Before conducting the research, each participant signed a consent form. For this research, both male and female workers between the ages of 18 and 60 were recorded. A total of 72 operators were recorded for this research. The sex ratio of the participants was 11:9 (female to male). Two digital cameras attached on 41.3 in. tripod stands were placed 1m apart at either side of the operator (symmetrically). The individuals were videotaped for two minutes (on either side) or two repetitions, whichever managed to come first. The captured videos have operations like collar attachment & making, sleeve attachment, over-lock, tab making, ruffle making, bottom hem, back yoke, keyhole, loop attachment, etc. It is also important to note that the factory followed Eton System or more commonly known as the hanger system for the manufacturing process. Apart from the videos of the operators, an ergonomics checklist was curated to understand the association of workplace design with the overall risk of musculoskeletal disorder in the factory workers.

3 Proposed Methodology

This section delves into the proposed methodology for the development of the Risk Assessment System for sewing machine operators. To obtain the final RULA score of the operator, several processes were involved. The flow of the proposed methodology for the development of this system is depicted in Fig. 1. To test the functioning of the system, several videos were analyzed and fed to check the outcome. The subsections that follow include a detailed overview of each move.

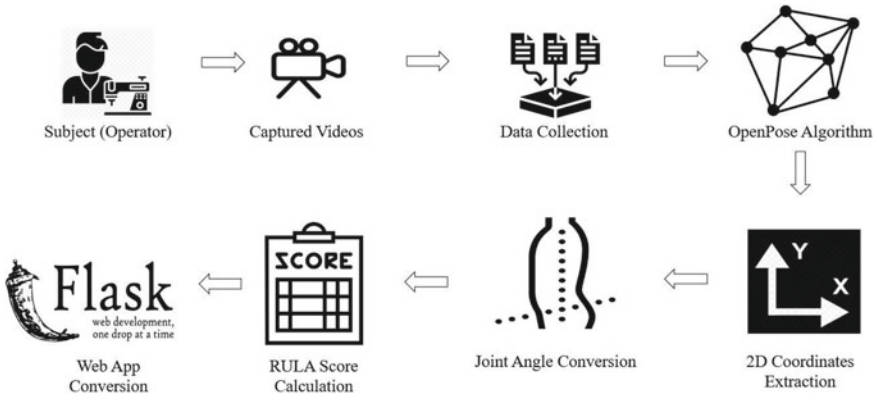

Fig. 1 Block diagram of the proposed methodology

3.1 Preprocessing

The preprocessing stage is critical for determining the level of risk of any operator or topic. By evaluating the same, instant measures can be taken like reducing the workload of the operator, assigning easier tasks, increasing break time, etc. This research had to undergo various preprocessing stages to reach that level. This stage consisted of a multi-step approach that used the cutting-edge OpenPose algorithm which takes the videos as input and outputs the desired result, that is the RULA score evaluation-action class and its interpretation. The OpenPose algorithm, developed by Carnegie Mellon University researchers, successfully detects real-time multi-person as well as single-person human features such as facial, hand, and foot movements, along with overall body movements, using crucial key-points detection on the rendered image frames [23].

Pose estimation can be done in two ways—2D and 3D, based on the requirements of this research, the 2D pose estimation technique has been followed by using the single-person pose estimation approach. The primary focus of the 2D pose estimation model is on tree-structured graphical models. They parametrically encode the spatial relationship and then further encode the relationship among the body components using either a non-tree model or a kinematic chain. Edges that represent occlusion, symmetry, & long-range linkages are then added to the tree structure [24]. A well-known method for predicting human poses in 2-Dimension is *Single Person Pose Estimation.* It's done by inferring spatial connections between body parts from a collection of local observations of body components [25, 26]. In the following subsections, a brief explanation of the algorithm along with its application is mentioned.

Algorithm Architecture. As established in the sections before, this research uses the OpenPose algorithm to study the posture of the sewing machine operators and then calculate the final RULA Score. The algorithm takes in the input (Fig. 2a) as RGB image frames, which is fed into a *'two-branch, multi-stage'* Convolutional Neural

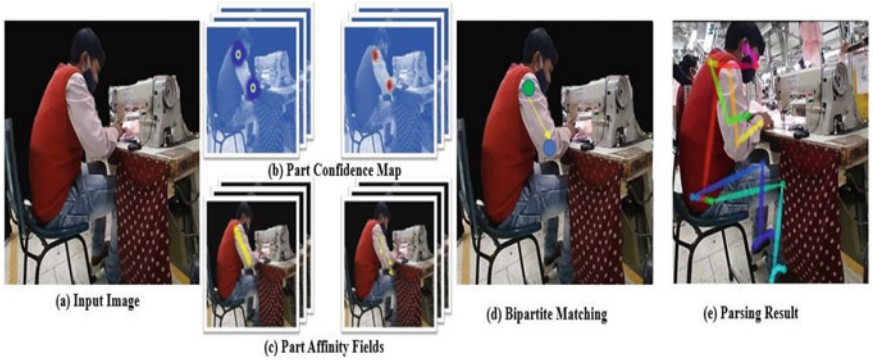

Fig. 2 Overall process pipeline- OpenPose algorithm

Network (CNN). This means that the CNN will create two distinct outputs, making it a multi-stage network, with each stage stacked on top of the previous, which enhances the depth of the neural networks involved. This helps to get a much more refined output which is then used for the following stages [23]. The upper branch, shown in blue in Fig. 2b, estimates the confidence maps of the human body such as the right elbow, left elbow, left and right wrist, and so on. The lower branch, Fig. 2c, then works to determine the part affinity fields, which represent the degree of linkage or association between human body parts [23]. The Greedy Bipartite Algorithm is used to analyze the above-generated Confidence Maps and Part Affinity Fields, as shown in Fig. 2d. In the Greedy Bipartite algorithm, a set of edges in a graph is selected in such a manner that no two edges in that set share an endpoint [27]. It contributes to obtaining poses for the input images, it outlines the basic skeleton of the human body for pose estimation, as seen in Fig. 2e [28].

Application. Now that the process flow of the OpenPose algorithm is clear, it is important to establish the remaining preprocessing steps taken to successfully extract the desired result of the RULA score of an operator. For this research, the data was collected in the form of videos, captured by digital video cameras. The OpenPose algorithm is applied to image frames, so necessarily, the first step was to convert the videos to image frames. One important thing to note here is that the OpenPose algorithm requires high functioning GPU access, so the entire setup was done on the Google Collaboratory Research platform which is an online cloud environment that is well suited for machine learning and data-driven programs. The following steps discuss all the steps taken to achieve the desired result:

1. **Upload the Videos in Compressed Format**. The videos were recorded using high-quality HD cameras, resulting in an average video size of 600 MB. To reduce the computational time, the videos were reduced to around 30 MB each.
2. **OpenPose Library Installation**. Installing the OpenPose library from the internet, specifically the GitHub repository.
3. **Break the Video to Image frames**. As previously stated, the OpenPose algorithm takes input in the form of an RGB image. As a result, the compressed clips are further divided into frames at 30 frames per second (f.p.s.).
4. **Application of the OpenPose Algorithm**. On the image frames, the algorithm works on the confidence map building and defining the part affinity fields, and ultimately makes the human skeleton on each frame based on the posture as shown in Fig. 2e.
5. **Define Key-points**. In this research, 25 standard key points have been defined and assigned a coordinate sequentially. For example—left and right heel, left and right toe, etc.
6. **Coordinate Extraction and its conversion to Angles.** As this is an Upper Limb Assessment technique, the coordinated for Upper and Lower arm, Trunk, Neck, Wrist, and Legs were extracted and then converted into angles using the math function of the python language. The values were stored in an excel format for future use.

7. **RULA Score Computation**. The values from the angles excel sheet was then assigned a specific score based on the range given in the RULA assessment sheet. For example, if the Upper Arm values lied from the range of −20–20°, the upper arm score was taken as 1 and subsequently for others. For each operator, the system gives about 120 values, which were then compared with the actual RULA sheet to get the final score and action class of each operator. The values of the table were scored as a CSV file and then were compared with the extracted values.

3.2 Framework to Application Conversion

With the framework ready, the entire model was converted into an application for easy processing. The OpenPose algorithm is built using a deep learning framework, Caffe, which doesn't support Android. It also requires high functioning GPU access to run, so to tackle those problems, a web application for this framework was created using Flask and ngrok tool. It is a quick and easy method to present the flask programs on any machine. It uses the efficient ngrok tool. ngrok is a free tool that lets us tunnel data from a public URL to a locally running application making it available across the internet. In Fig. 3, the final web application is showcased. While the back end of the program contains a lot of multi-step processes, the interface is kept just as simple and user-friendly. The user needs to specify the side profile of the video,

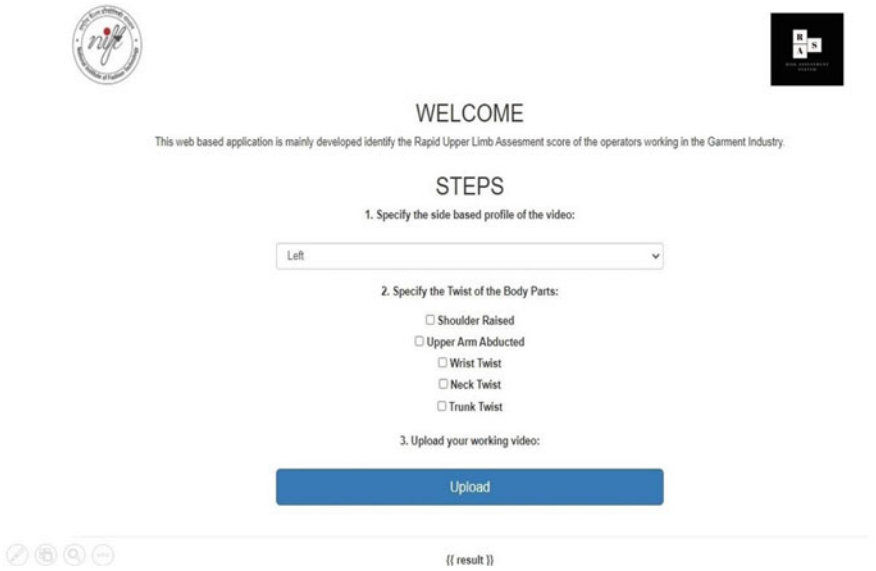

Fig. 3 The interface of the Web Application

define the wrist twist, neck twist, or any other conditions, by selecting the values and then finally upload the video. The system will process the data and give the result.

4 Results and Discussion

This section discusses the results achieved on the completion of this study. To assess the risk level of the operators of the garment industry, a Risk Assessment System was successfully developed with the help of a state-of-the-art machine learning approach—the OpenPose algorithm. Accurate estimation of 2D human poses was one of the most crucial aspects for the success of this work. When compared to other pose estimation algorithms, OpenPose is considered much more accurate [23]. Yet, to test the validity of this model, a KNN model was created to check the accuracy of the results. The model classified the subjects (operators) into two categories—healthy (normal) and unhealthy (abnormal). The accuracy came out to 91.3% (±2.1), making it a reliable solution for assessing the risk level of the garment industry operators.

Table 1 showcases the maximum values of the angles extracted from the working videos of the operators and the most commonly observed/average RULA score range. The task is mentioned alongside the angle. Here, we can see that the angles extracted are of the upper & lower arm, neck, and trunk. the value for the wrist in the RULA assessment is always considered as one due to the limited range of movement while working. The RULA score of 7 indicates a very high-risk level while the range 5–6 indicates a high-risk level.

A limitation to this study is that while calculating the RULA score, the user needs to input certain conditions like the presence of wrist twist, shoulder abduction, neck, twist, etc. Due to the unavailability of prior research, the system cannot be trained to detect these conditions. Another important thing to note here is that this system is developed for the sole purpose of the risk assessment. It can work as a guiding tool

Table 1 Maximum values of the angles and average RULA score range observed during an operation

Operation	Upper arm	Lower arm	Neck	Trunk	Average RULA score range
Collar making	−66.09	22.87	−31.88	−65.37	7
Sleeve attachment	−91.04	− 37.80	−18.44	−62.28	5–6
Back yoke attach	−67.54	56.69	−32.80	−61.24	5–6
Armhole attach	−51.14	31.23	33.96	17.17	5–6
Overlock	−60.66	14.25	45.83	−54.08	7

*This data is of the left profile of the operators. The range of the RULA score (values) was adjusted according to the negative values received from the data. The unit of measurement is the degree for all the values.

yet it cannot improve the posture of the workers, that needs to be done separately with the help of exercises and in consultation with the medical experts.

5 Conclusion and Future Work

With each passing day, the risk of Work-related Musculoskeletal Disorder is increasing rapidly. Its prevalence in the garment industry is also making a permanent place. At this stage, the decision-makers need to take this issue very seriously.

This assessment system will not only information about the risk level of MSD in an operator but will also prove to be a guide. Based on the results of this system, appropriate actions like increasing break time, appropriate changes in the skill matrix, workload reduction, etc., or whatever changes the organization may see fit. If the health of the workers is taken care of, there will be a significant change in the absenteeism rate and might also increase the overall productivity. Many various forms of experiments, testing, models, and so on have been left out for the future due to a time constraint. The subject matter itself is extremely wide, with virtually endless possibilities for investigation. The following future work can be carried out based on this research:

1. A study can be conducted to investigate the relationship between the socio-economic status of the operator with the risk levels of Musculoskeletal Disorder.
2. The model could be tested against other classifiers-machine learning algorithms to test the validity of the system.
3. An updated skill matrix for the production department may be prepared based on the skill set of the workers and their risk of injury level, in which tasks will be allocated to each operator based on their abilities and risk of injury.
4. A machine-learning algorithm could be prepared for the early risk prediction of MSD in the sewing machine operators of the garment industry.

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Design Implementation and Academic Correlation for Harmonizing Contemporary Usage and Heritage of Bodo Traditional Attire

Chaitali Brahma, Bhaskar Saha, and Debkumar Chakrabarti

Abstract Dokhona, a traditional women's attire of the Bodo Community of the northeast India, marks the community's cultural and traditional identity besides being a ubiquitous dress for daily use. However, in order to cater to the need of (i) convenience in performing daily chores, (ii) ease of wearing from health and safety considerations, (iii) contemporariness of taste and style of dressing, (iv) preservation of the Bodo heritage embodied in Dokhona, and (v) sustenance of traditional looms and cottage industries, the requirement is felt for innovation in the design, production and usage of this dress item. During research on innovative designs of Dokhona, it was found from a status investigation from weavers, users, designers and medical practitioners that elderly people prefer no changes, whereas the younger generation prefers comfort and utility in the context of modern styles of living, and that the retention of the traditional look while bringing in contemporary trends of fashion and feel is important. Additionally, it was found that intervention through academic linkage by designing suitable multi-level programmes, reference the Central Institute of Technology Kokrajhar in Bodoland Territorial Region, could be looked into as a novel approach for up-skilling the traditional artisans and weavers, modernizing the traditional looms, encouraging entrepreneurs and designers, and giving impetus to business development for enhancing return on investment and income of various stakeholders involved with Dokhona. This paper emphasizes innovative ways for motivating young minds through hands-on practice for bringing about sustainability in cultural heritage by rendering versatility and contemporariness in the design of Dokhona through academic interventions.

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Keywords Dokhona · Cultural identity · Contemporary design · Academic intervention

1 Introduction

Traditional knowledge is storehouse of information, know—how, skills and practices that are developed, sustained and passed on from generation to generation within a community, often forming part of its culture. Education upholds the continuity of culture through its diverse activity and programs. However, traditional knowledge as such has ancient roots and is often oral. A society establishes its academic basis to preserve and transmits its culture. Traditional knowledge can be benefited from research, innovation based on patent, trademark and geographical indication protection [1]. Handmade textiles are an important source of traditional knowledge. With rapid social changes, the transmission of technology and the content of these textiles becomes difficult to maintain [2]. For an indigenous weaver, the traditional weaving materials and tools are natural and are made from the surroundings [3]. This attempt relates to the exploration of traditional knowledge of an indigenous community of North east India, especially that of the Bodos tribe, who have developed a high sense of traditional weaving techniques. The art of traditional weaving has been transmitted in Bodo community has been passed from mother to the girl child from generation to generation. However, there is no formal practice of skill learning techniques which could sustain and contribute to cultural inheritance. As a result, the traditional indigenous way of weaving techniques is facing difficulties in safeguarding their heritage. The analysis of this study provides an important reference for the feasible need to carry forward indigenous techniques from the brink of disappearing from the Bodo community, and provides the opportunity for reconnecting cultural ecosystem through technical and formal academic linkage.

1.1 Genesis of the Bodos

The Bodos are the largest ethno-linguistic group in the state of Assam in the north-eastern region of India. They belong to the Bodo-Kachari family and are spread across the region. A major concentration of the Bodo people is in the Bodoland Territorial Area Districts (BTAD) of Assam shown in Fig. 1. The Bodo-Kachari people are prehistoric settlers who are believed to have migrated around 3000 years ago from Tibet through the Bhutan passes.

The word ‘Bodo’ is derived from the word ‘Bod’ meaning Tibet. The Bodos were the first people to rear silkworms and produce silk materials. They were considered to be advanced in rice cultivation during that period. The Bodo people are recognized as a plain tribe in the Sixth Schedule of the Indian constitution and are conferred with special powers in the BTR. In the state of Assam, the Bodo tribe is known to be the

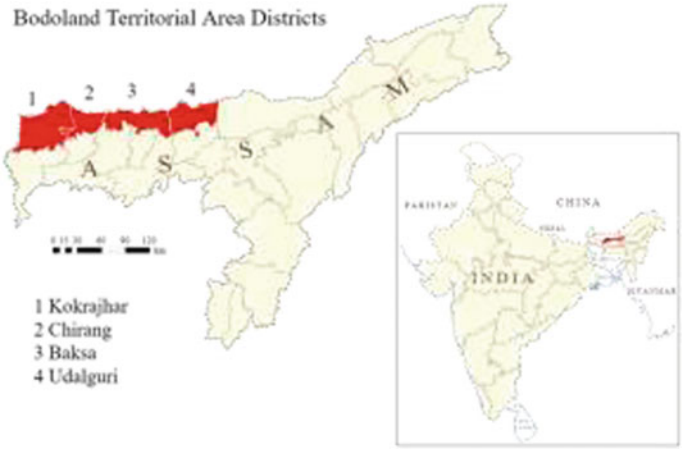

Fig. 1 Map showing Bodoland territorial areas districts [4]

earliest immigrants with major concentration in the northern side of the Brahmaputra valley, and play an important role in the culture and tradition of the state. Kokrajhar town is regarded as the hub of Bodo tribal community [5]. The Bodo culture is found to be a part and parcel of the Indo-Mongoloid culture that has greatly influenced the culture of Assam [6]. Their rich culture integrates essentials like dancing, singing etc. that reflects the fact that they have many religious practices and beliefs among which Bathouism has a special importance. Bodos are fond of Zu mai, which is their conventional drink. This drink is been offered as a mark of respect when people visit their homes. Bodos are mainly non-vegetarian and relishes pork and fish. Oma, onla, narzi are their cuisines; still the preferred motifs in Dokhona are predominantly of vegetative origin. Baishagu is the main festival and is celebrated during the month of April every year where new Dokhona comes as a gift from elderly.

1.2 Significance of Dokhona and Culture

Bodos have exquisitely elaborate dress items particularly expressing the beauty and glamours of women. The traditional attire worn by the Bodo women is known as Dokhona, which they themselves weave on their looms. Thus, a loom is the most significant thing cast off in the courtyard of a Bodo household. It is said that a Bodo woman weave their dreams through their looms [7].

The traditional Bodo Dokhona covers from chest to ankle and is usually 2.5–3 m with a width of 1.5 m. It is worn by tying knots, one around the chest and the other around the waist [8]. The designs embedded in Dokhona are picked from nature. In recent times, cultural globalization could be noticed amongst the Bodos wherein ideas, meaning and values are getting disseminated around the world in such a way

Fig. 2 Image of traditional Dokhona

as to extent and exaggerate the traditional values. This has marked the common consumption of change in the dressing pattern of the Bodo females and has been largely diffused through the way of internet, popular media and international travels [9]. A picture of a full length traditional Dokhona is exhibited at Fig. 2.

The uniqueness of Bodo traditional attire Dokhona itself is a symbol of its cultural identity. In the present scenario, it is noticed that the Bodo women are getting influenced by western outfit that creates debate on its sustainability, with reference to its discomfort arising from safety point of view as well as from its comfortability level. With the advent of fast life, it has also been seen that there is a steady rise in the consumption of styles amongst the Bodo women, which have added to a renewing feature enhancing the existing look and feel of the customer [10].

1.3 Globalization and Change

The contemporary globalization has produced many changes in India's economy, society, culture and politics. The quality of resilience that India had shown earlier is slowly diminishing now. Certain aspects of India's multi-cultural fabric have been showing acceleration in the growth of self-consciousness and cultural identities due to globalization. As a result, several aspects of India's customs and tradition tend to exist side by side depending on both adoption and rejection [11].

The effects of globalization are also seen in Bodo culture. In the earlier days the men used to wear vest made of cotton or endi which is rarely seen today. The Bodo Christians use white colour Dokhona for marriage purposes in conformity with the western style of dressing. The men wear suit in the place of traditional gamocha during the occasion. The new generation is not found of wearing the traditional wear

Dokhona as the western and other Indian attires are a comfortable option to Dokhona. As the demand for Dokhona falls the looms are threat of losing their own traditional dress in the near future. With the advent of westernization, the Bodo women do not want to keep sticking to older styles. They want to adopt new modern innovation fashion regarding their dress. Lot of changes in traditional cultural practices has been observed among the Bodos. The Bodos are undergoing the process of modernization, acculturation and urbanization. The impact of these factors on them is resulting in diminishing the traditional values and folk culture [12].

1.4 Ethnic and Preserve the Bodo Tradition Culture

The conception of Bodo women ethnicity through clothing from traditional to modern Dokhona can be relatedly seen to transform (Fig. 3a–c). Unlike traditional attires that validates regional and national attachments, modern western clothes doesn't showcase any of these functionaries in the Bodo culture.

In some regions customs are still pertinent as a living tradition, however traditional clothing is still disappearing from everyday life. Ethnic style using regional and national traditional does not always showcase a person's nationality. Yet, these days modern clothing foreseeing ethnicity can be instituted. Ethnodesign, shadows a considerate care about the tradition which gains pertinent due to rise in globalization establishing escalation of regional differences. The exponents of ethnodesign claims the ability to contribute to traditional symbols into modern culture [13].

Fig. 3 Transformation in Dokhona

The Bodos since old days have accepted Dokhona as a costume to be the most important means of Bodo identification. This function of Dokhona did not lose its relevance till today. A costume allows one to decide an individual's social group [14].

The presented pictures (Fig. 4) clearly show the Bodo women wearing an urban attire aligned with Bodo traditional motifs engraved in Dokhonas. But to what level this can sustain the Bodo designs is also a matter of thought. In the photo taken recently (Fig. 4) shows that the young generation wants to move with the flow of modern dressing and the use of Dokhona as an daily cores are almost gone. This demonstrates the fact that people from the villages adapt the urban fashion. In the recent times tradition customs are seen to be worn rarely and only for special occasions, predominately weddings and while performing religious prayers. This generates a symbol of traditional identity and self-affirmation. The gradual disappearance of traditional clothing from everyday life specially in the vicinity of the study area i.e. Kokrajhar had witnesses the loss of the function of envisioning ethnicity was accompanied by a demand to accept western clothing as a source of innovation. Same as their ancestors modern Bodo women value their customs that allow not only intitling the social status of the wearer but at the same time it designates the political views as well as social and environmental positions. Thus, it can be stated that at the present time the traditional Bodo Dokhona has been disappearing from daily life.

Despite wide spread of urban fashion and disappearance of traditional Dokhona as daily wear, partial preservation of purpose of ethnicity in modern costume can be noted. This can be showcased and worn only during special occasions mostly

Fig. 4 Modern urban attire through the Bodo traditional motifs

weddings and during certain cultural programs organized by the state to symbolize national identity and self-assertion.

The more the younger generation drifts towards modern comfortable clothing, the more the disappearance of the traditional wear. Here, we need to groom the art of weaving amongst the young lots. As part of academic and skill, the ancestorial occupation of weaving in looms need to be revived. As a part of technology study, the indigenous art form should be incorporated in the course content of study through hands on practice skills. As weaving is an essence of Bodo culture and is practiced amongst the Bodo women, it needs to uphold this indigenous treasure.

This paper emphasizes means and innovative methods ways for motivating young minds through hands-on practice for bringing about sustainability in cultural heritage by rendering versatility and contemporariness in the design of Dokhona through academic interventions. It is anticipated that the proposed an academic linkage would help upgrading the Bodo pride in Dokhona and ensure sustenance of Dokhona in the Bodo society with ideas integrating Bodo traditions with modernity, thereby making Dokhona an acceptable wear at all times for all age groups and for all functional usage.

2 Aim and Objectives

The aim emphasis on the weavers' perspective and enhancement of weaver's skills and techniques for sustaining and preserving the Bodo traditional attire.

- To look into the status of children of weavers' family engagement in weaving as profession through education.
- To introduce the design aspect of learning amongst the weavers.

In order to fulfill the objectives, it has been hypothesized that students learn requirements in terms of entrepreneurial skill development when a design thinking methodology is introduced to them, and that academic intervention supports the sustenance of a tradition that would hold good in the case of Dokhona, the traditional wear of Bodo women.

3 Methodology

The study was undertaken in the Dept. of Sericulture BTAD, Kokrajhar, Assam. This Dept was chosen as it is the only place where skill practices have been imparted to the weavers. The training is imparted to young weavers about the advance technology and their knowhow. The total numbers of participants were 59 (including 11 training officers, 39 trainees and 9 professionals). The approach considers a qualitative enquiry comprising direct observations on present practice of use and manufacture, feedback opinion survey with purposive random select stakeholders, i.e.,

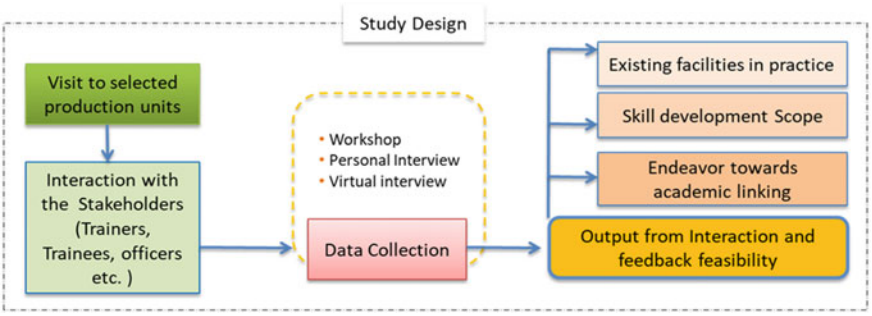

Fig. 5 Study design steps followed during the study

Fig. 6 Interaction with officers and trainees etc. Dept. of Sericulture, Kokrajhar

relevant users, producers, leading personalities in the society, social development officials and designers and academicians.

Direct observation and qualitative enquiry on present practice, common perception and feedback opinion survey with purposive random selected stakeholders leading to conceiving an academic programme in Design to cultivate contemporary newness to various heritage identities: the current work is in reference to Dokhona—the Bodo tribal women traditional wear.

The study design shown in Fig. 5 was framed so as to select a production site where skill and hands on training was imparted. As a case study Department of Sericulture was selected as a workplace conditions and assessments by the way of interaction with the stakeholders namely trainers, trainees, officials were intervened. This was done through workshop, personal and virtual interview.

It brought about the collection of data for the study after being tested for validity and reliability and personal interviews followed by visual interpretations of the workplace. Respondents were explained the purpose of research in detail and explore the scope of improvement through personal interviews. All the respondents were administered individually to have their individual opinion with confidentially assured.

In addition to reviewing the literature of this topic, interviews with top authorities and other stake holders have been included to illustrate the changes in the Bodo women wear Dokhona viewing their comfort and safety.

The interactions with officials and trainees at the Department of Sericulture is depicted at Fig. 6. The opinions and comments received from the individuals who

participated in the interview related to the conformability and sustainability through entrepreneur skill development of the Bodo Dokhona is discussed in the para below.

To have a better understanding about the main skill delivered to the weavers specially to weave the Bodo traditional attires namely Dokhona and about the techniques of weaving imparted to the interested females, interaction with eleven training officers from the Department of Sericulture Kokrajhar was undertaken. During the course of interaction, the training officers opined on the newness and desirable changes need to be brought into Dokhona if the question of sustainability of this traditional wear is to be uphold. Innovation in comfort should be studied by blending of weaving materials. Bodo youth of today need to be equipped with latest technological knowhow as traditional methods will not sustain in modern day's clothing fashion Incubation centres need to be opened up. Focus on appellate garmenting is necessary. Training would benefit young youth specially the Bodo girls for their interest in weaving. Hands on training on weaving is a good way to revive the age long traditions of the Bodos. Everybody welcomes change, so do change is required in Bodo traditional attire.

After acquirement received from the officials of the Dept. of Sericulture, Kokrajhar, Govt. Of Assam, the trainers were interacted to have an understanding about their willingness to learn advance skill, techniques and design aspects for better communication in a cognitive way. Thirty-nine (39) trainees as a sampling have been taken to extract the ideas how hands on practises can be benefited to an individual. They were of the view that with change in technology they should also update themselves. With the advent of modern technology, the traditional and the indigenous method of weaving has no heft. Some have commented that trainees feel empowered after learning skills. As Dokhona after weaving becomes heavy which in turns is very difficult to use in today's fast life. With the new machineries the generation of weaver's family have the interest to learn and cope up with the changing technology with the aim of keeping the legacy of traditional practice of weaving alive. The Bodo tradition of weaving needs to be sustained. Some cited that with the change of technology the heavy dokhona may be felt light and comfortable. They can revive their old traditions with a new look. Some trainees also extended this skill towards formal education specially the ones who were dropped out from school. They were of the view that their traditional attire should be able to compete with the other comfortable dress available at the market. This newness may attract users and thus motivate the younger generation to wear Dokhona. Bodoland being at the proximity to Bhutan attracts huge tourist. Tourist all over the country and also from abroad visit the famous Manas Reserve Forest. They find some uniqueness in the Bodo traditional dress. As such if Dokhona is designed in such a way, then it would have been much user friendly.

3.1 Outcome from the Interactions

The overall outcome from the interactions from the training officers and the trainees of the Dept. of Sericulture, Govt. of Assam are as follows:

- To provide hands on training on the advance technology to be used on weaving of Dokhona to make the produce more susceptible for use through design thinking.
- To get hands on training on better skilling practices so that the product, specially Dokhona will be in demand and user concentric.

This study outcome emphasises on the need for an institutional platform where hands on practical skills and techniques with the help of design aesthetic is module to be designed in an innovative way. Further discussion with the different professionals, designers, educationist, health workers were intervening to seek the need for problem solving related to issues pertaining to Dokhona. The observations pertaining to the discussions with the professionals have optioned that wearing Dokhona for longer duration leads to chest pain for the reason, the very material being heavy. The chest holds the heaviness of the cloth as its tugged in just above the breast. Regularly keeping a check from slipping. Today's women have become empowered and pragmatic. Comprehend the smooth transition from Tradition to Modernity. Perhaps, if Dokhona was made of a lighter material it would be more comfortable to wear on a regular basis and would be considerably recommended for travelling and full-time wear. Doctors pointed out about the health issues and materials to be used while weaving the costume. Regular use of tight garments specially in the chest may cause breast cancer due to constant friction leading irritation. Hence, new design thinking wear is needed to be studied to suit the comfort. This can be done through design studies.

Garment designers were of the views that a Bodo female could either practice wearing Dokhona in their household or try variations in those points of drape where an individual finds uncomforting. Traditional Dokhona required some modifications in the designed and pattern for extensive usability in all activities. Some social activists were of the views that although Dokhona is not very convenient and comfortable during summer due to its thick fabric, still one should wear it to keep the tradition alive. This can be done if new design is brought into the market and are user friendly. Indigenous weaving of Dokhona in household looms results in rough weaving of attire. Hence formal training to use machine made looms may be opted for. Academician were of the view that academic intervention is the need of the hour. Technical institute should propose courses on harmonising academic with preservation of culture heritage. Preserving the traditional look is a part of the socio-cultural progress though requires modification and new approaches of apparel design according to needs appropriate for the future aspect.

Although the elements and styles of the traditional Bodo culture are been included these days by the Bodo designers to match up with the modern material culture through the means of ethnic style. This adheres to attract the young generations. The upcoming weavers also knowing that the demand of Dokhona is on decline and in

course of time might have to go for different means of living, tries to work in ethnic styles, trying to borrow and transform the elements of national customs from different regions and sometimes combining them to build up a creative source. This often had led to insincere and shallow insolence towards the originality of the indigenous art form of Bodo motifs. The ornamental motifs, pattern colour combinations and shape are all seen to be distorted without even caring about preserving their original traditional Dokhona.

3.2 Academic Correlation or Linkage Leading to Motivation

A thorough observation of the comments from various delegates emanates a dire need of an entrepreneurial skill-academic linking to sustain the practices of traditional weaving skills through innovative education. This deliberation reports confirms the need for innovative education and design intervention leading to a stress-free wear of Dokhona whilst preserving the practices of traditional weaving skills. The United Nations Development Programme (UNDP) extended help in promoting technical and corporation helps in capacity building and advocated resources to help people build a better life. In a recent meeting held at CIT Kokrajhar on development issues of local children, the thought of skill development linking academic certificate was welcomed as an appropriate approach where the school dropouts could be re-admitted into the academic time-line. An experimental attempt is made here is by CIT Kokrajhar about an indigenous Bodo tribal community of Assam located in Kokrajhar district to uprights with the vision to promote vocational skill and training and mission to serve as a link between education and self-reliance through edge skills and on the job training.

CIT Kokrajhar is developing a multi-level scheme (with ease of entry and exit) with entrepreneurial approach for school dropouts and young ones. Course content depending on level of programmes is expected to cover heritage introduction; understanding history of identity creation and elements thereby; design development fundamentals to value addition, ergonomics and usability issues, production issues including workplace, work equipment, manpower & manufacturing, and marketing issues with recent regulations shown in Fig. 7.

According to Majhi, hands-on experiences and projects would take major content weight so that learners can get self-motivated [14].

In the context of making the use of Dokhona stress-free and acceptable across generations of Bodo women while retaining the traditional look and feel, it is therefore imperative that CITK takes lead in up-skilling the traditional artisans and weavers, modernizing the traditional looms, encouraging entrepreneurs and designers, and giving impetus to business development for enhancing return on investment and income of various stakeholders involved with Dokhona. This intervention would be possible through innovative academic linkage supported by the designing of appropriate programmes in the Institute. Thus, emphasizes innovative ways for motivating young minds through hands-on practice for bringing about sustainability in cultural

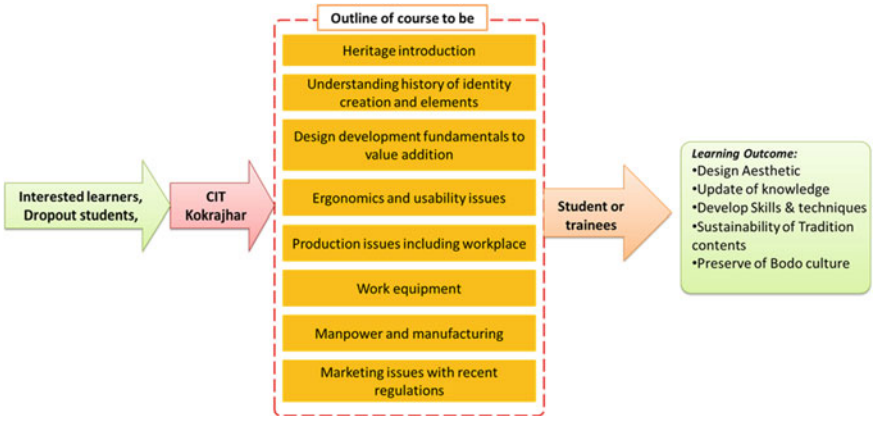

Fig. 7 Outline of the proposed course

heritage by rendering versatility and contemporariness in the design of Dokhona through academic interventions. It is anticipated that the proposed academic linkage would help upgrading the Bodo pride in Dokhona and ensure sustenance of Dokhona in the Bodo society with ideas integrating Bodo traditions with modernity, thereby making Dokhona an acceptable wear at all times for all age groups and for all functional usage.

The Government of India is bringing a series of reforms to usher the constructive changes on skill development as a key element of the modern education system. With the vision to make the youth "atmanirbhar" through skill-based education and thus to make the country "Atmanirbhar Bharat", the National Education Policy (NEP) 2020 has been crafted accordingly. The NEP 2020 provides the students of middle level shall be exposed to hands on training in vocational skills like carpentry, plumbing, electric repairing, horticulture, pottery, embroidery etc. This policy has targeted providing vocational skill at least to 50% students by 2025 in such a way that vocational skills acquired at school level may be extended up to higher education level, depending on the requirement of the individual students [15].

4 Conclusion

Entrepreneurial skill development through a design thinking methodology and academic intervention supports the sustenance of an indigenous tradition that would hold good in the case of Dokhona, the traditional wear of Bodo women. In order to cater to the need of convenience in performing daily chores, ease of wearing from health and safety considerations, contemporariness of taste and style of dressing,

preservation of the Bodo heritage embodied in Dokhona, and sustenance of traditional looms and cottage industries requires innovation and modernization in the design and production for popular usage.

The weaving of a Dokhona is an age-old tradition of the Bodo tribes. Every household had a loom to weave their dream, which is disappearing now. It can be overcome only through recommended plans which intensify the output and wellness of the Bodo women. The study recommended that Government should boost additional consideration to make enhance the skills of the young weavers and bring professionalism in their art. The real-time scenario is "creative ergonomic design interventions", to alleviate stress in adorning Bodo Dokhona by the young generations and uphold the Bodo traditions. Focusing on the next generations as the owners of the heritage, development of education approach for children is an important issue which would support to sustain the culture of the society. The provision of possibilities by which children can get familiar with cultural treasures would support to sustain society which would deliver the cultural values more effectively. Thus, it becomes important to consider educational approach for children to promote their knowledge on the essence of cultural heritage.

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Assessing Lung Functions Status in Male Human Resources Engaged in Wood Processing Works Using Surrogate Markers

Tanaya Santra, Sandipan Chatterjee, Surjani Chatterjee, Sweety Bardhan, Neepa Banerjee, Baidyanath Pal, Somnath Gangopadhyay, and Shankarashis Mukherjee

Abstract Occupational lung disorder is becoming one of the major threat to human health in recent times and thereby, rate of mortality and morbidity is on high. Therefore, early assessment and diagnosis lowers the rate of such kind of lung functional abnormalities. In this background, a study was carried out on 37 Bengalee males (24–36 years) involved in wood processing works to assess their lung functions condition and to find out and/or validate the relationship, if any, present between select anthropometric variables and PEFR. Stature (cm), body weight (kg), trunk length (TL) (cm), arm span (AS) (cm), acromion height (AH) (cm), radial height (RH) (cm), stylion height (SH) (cm), dactylion height (DH) (cm), sitting height (Sit H) (cm), chest circumference (CC) (cm), waist circumference (WC) (cm), and hip circumference (HC) (cm) were measured, and PEFR was measured. Select anthropometric variables were significantly ($P < 0.05$) associated with PEFR. Mathematical models were developed validated for use.

Keywords Pulmonary functions · Mathematical models · Occupational wellbeing · Anthropometry

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1 Introduction

Occupational hazards are considered as major contributing issues having negative impacts on wellbeing of human resources employed in different occupational settings and its prevalence is on rise silently in recent times. Additionally, it is very obvious that prolonged exposure and inhalation of hazardous substances in the workplace, produces several respiratory symptoms among working individuals [1, 2]. In organized sector, pre-employment and period medical examination including assessment of lung functions is a statutory requirement. But, it is not mandatory in various occupations in unorganized and informal sectors. Wood processing industry, one of the age old unorganized working sector in India, has immense contributions in various aspects of mankind i.e. fuel to livelihood, luxury to modernization from past to now. Moreover, wood processing works involve exposure to wood dust that produces several respiratory abnormalities and it is estimated that worldwide at least 2 million people are exposed to wood dusts causing deterioration in pulmonary functions [3]; however, peak expiratory flow rate (PEFR) is an authentic as well as non-invasive effort dependent pulmonary function indicator which easily diagnoses any kind of airways obstructions and air trapping related disorders among individuals. [4–6]. Anthropometry which provides information regarding human body morphology has impact on pulmonary functions; thereby, surrogate markers in terms of anthropometric variables might be used to assess the functionality of lungs. Therefore, in this context, the current study was conducted on human individuals involved with the wood processing works to evaluate the functionality of lungs and to find out and/or validate linkage, if any, present in between some select surrogate marker, that is defined as a laboratory measurement or somatic mark, that is used as a substitute for a clinically meaningful endpoint that is a direct measure of how a patient feels, functions and is expected to predict, used in this present study as anthropometric variables and PEFR, indicator of lung functions as demonstrate in pulmonary function tests.

2 Methodology

The present study was conducted on adult Bengalee males residing in south Bengal in the state of West Bengal, engaged in wood processing works. At the beginning, the Human Ethical Clearance (HEC) was taken and the study requirements were explained to the individuals. The names of consenting human individuals were listed. All the measurements were taken on mutually convenient dates. 37 individuals aged between 24 and 36 years, fulfilling the criteria formed the study group (SG). Individuals with any history of personal or familial (self-reported) respiratory disorders and smokers were excluded; and, individuals (self-reported) having at least three years of working experience, with minimum six hours (on an average) of regular working hour was included in this present study. The information regarding their age (year),

working experience (year), socio-economic status, and daily activities [7, 8] of individual participants was collected. Some basic physiological parameters in terms of systolic and diastolic blood pressure (mmHg) and heart rate (beats min^{-1}) in pre work conditions were recorded [9]. Surrogate markers in terms of some select anthropometric variables-stature (to the nearest accuracy of 0.5 cm), and body weight (to the nearest accuracy of 0.1 kg) [10–13], using anthropometric measurement set and a pre calibrated weighing scale, were recorded. Trunk length (TL) (cm) [14, 15], arm span (AS) (cm) [16, 17], acromion height (AH) (cm) [12, 13], radial height (RH) (cm) [12, 13], stylion height (SH) (cm) [12, 13], dactylion height (DH) (cm) [12, 13], sitting height (Sit H) (cm) [13], chest circumference (CC) (cm), waist circumference (WC) (cm), and hip circumference (HC) (cm) [13], were recorded, with subjects in light clothing, without shoes and in standing posture using an anthropometric measurement set and non-stretchable measuring tape. Body mass index (BMI), and body surface area (BSA) were calculated. Afterwards, subjects were asked to take rest for at least a period of 15 min and after that, peak exploratory flow rate (PEFR) (l min^{-1}) was measured as per the guidelines of American Thoracic Society (ATS) [18, 19]. Pearsonian correlation was carried out to study the relationship status between the select anthropometric variables and PEFR. Subsequently, regression modeling was carried out and developed mathematical models were validated with the help of a new dataset of randomly chosen 43 human individuals constituting the Validation Group (VG) who have similar kind of socioeconomic strata as SG individuals. The obtained data were statistically analyzed and $P < 0.05$ was considered as level of significance.

3 Results

The background particulars of SG individuals are given in Table 1.

The values of select anthropometric variables and PEFR, indicator of pulmonary functions of SG individuals are computed and given in Table 2.

The magnitude of correlation between select anthropometric variables and PEFR is graphically presented in Fig. 1.

Table 1 Background particulars of SG individuals

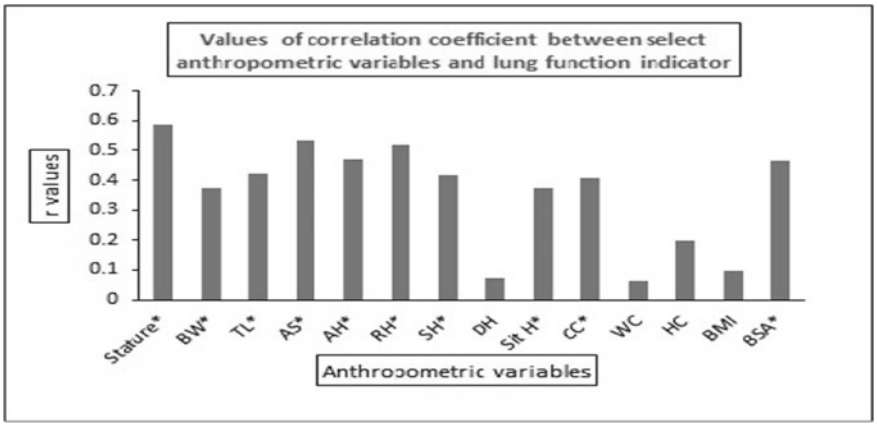
Parameters	Values
Age (years)	30.8 ± 5.60
Working experience (years)	10.5 ± 5.42
$SBP_{Pre\ work}$ (mm Hg)	129.6 ± 12.28
$DBP_{Pre\ work}$ (mm Hg)	86.1 ± 9.38
$HR_{Pre\ work}$(beats min^{-1})	82.1 ± 12.65

AM ± SD

Table 2 Anthropometric variables and PEFR of SG individuals

Parameters	Values
Anthropometric variables	
Stature (cm)	163.2 ± 6.71
Body weight (kg)	59.2 ± 9.72
Trunk length (cm)	48.2 ± 3.36
Arm span (cm)	168.0 ± 7.41
Acromion height (cm)	135.5 ± 6.51
Radial height (cm)	103.3 ± 4.95
Stylion height (cm)	79.3 ± 3.69
Dactylion height (cm)	60.2 ± 3.68
Sitting height (cm)	84.2 ± 3.05
Chest circumference (cm)	92.3 ± 5.83
Waist circumference (cm)	84.0 ± 8.77
Hip circumference (cm)	91.9 ± 6.43
Body mass index (kg m^{-2})	22.1 ± 2.62
Body surface area (m^2)	1.63 ± 0.15
Lung function indicator	
Peak expiratory flow rate ($l.min^{-1}$)	559.5 ± 82.6

AM ± SD



*P < 0.05

Fig. 1 Values of correlation coefficient in between select anthropometric variables and PEFR of SG individuals

Table 3 Regression equations for estimating pulmonary function indicator (PEFR) using anthropometric variables of SG individuals

S. No.	Anthropometric variables (predictors)	Lung function indicator (criterion)	Regression equations	F values	*P* values
1	Stature in cm (X_1)	PEFR ($l.min^{-1}$)	$\hat{Y} = -623.66 + 7.2476 * X_1$	18.597	0.0001
2	Body Weight in kg (X_2)		$\hat{Y} = 370.91 + 3.1842 * X_2$	5.720	0.022
3	Trunk Length in cm (X_3)		$\hat{Y} = 61.225 + 10.336 * X_3$	7.509	0.010
4	Arm Span in cm (X_4)		$\hat{Y} = -441.03 + 5.9546 * X_4$	13.984	0.001
5	Acromion Height in cm (X_5)		$\hat{Y} = -250.0 + 5.974 * X_5$	9.955	0.003
6	Radial Height in cm (X_6)		$\hat{Y} = -333.61 + 8.645 * X_6$	12.881	0.001
7	Stylion Height in cm (X_7)		$\hat{Y} = -155.11 + 8.9996 * X_7$	7.314	0.010
8	Sitting Height in cm (X_8)		$\hat{Y} = -289.06 + 10.074 * X_8$	5.605	0.024
9	Chest Circumference in cm (X_9)		$\hat{Y} = 26.79 + 5.7717 * X_9$	6.960	0.012

Based on the significant ($P < 0.05$) positive correlation in between select anthropometric variables, the surrogate markers and PEFR, simple regression analysis was done to develop prediction equations involving anthropometric variables as predictors and PEFR as criterion. The mathematical models are given in Table 3.

The developed regression equations using anthropometric variables as predictors and PEFR as criterion, are presented graphically in Fig. 2.

Based on the highest positive correlation, found between the two anthropometric variables, the surrogate markers in the present study-stature (cm) and arm span (AS) (cm) and PEFR, multiple regression model is developed and given in the Table 4.

Generated mathematical equations were validated on VG individuals (n = 43) who were again from the similar kind of socioeconomic strata as SG individuals. The background particulars of VG individuals are given in Table 5.

The values of anthropometric variables and PEFR of VG individuals are computed and given in Table 6.

The PEFR, indicator of lung functions, value as estimated from the regression equation presented in Table 4 were compared with the measured value of PEFR of the VG individuals; there were significant ($P < 0.05$) correlation.

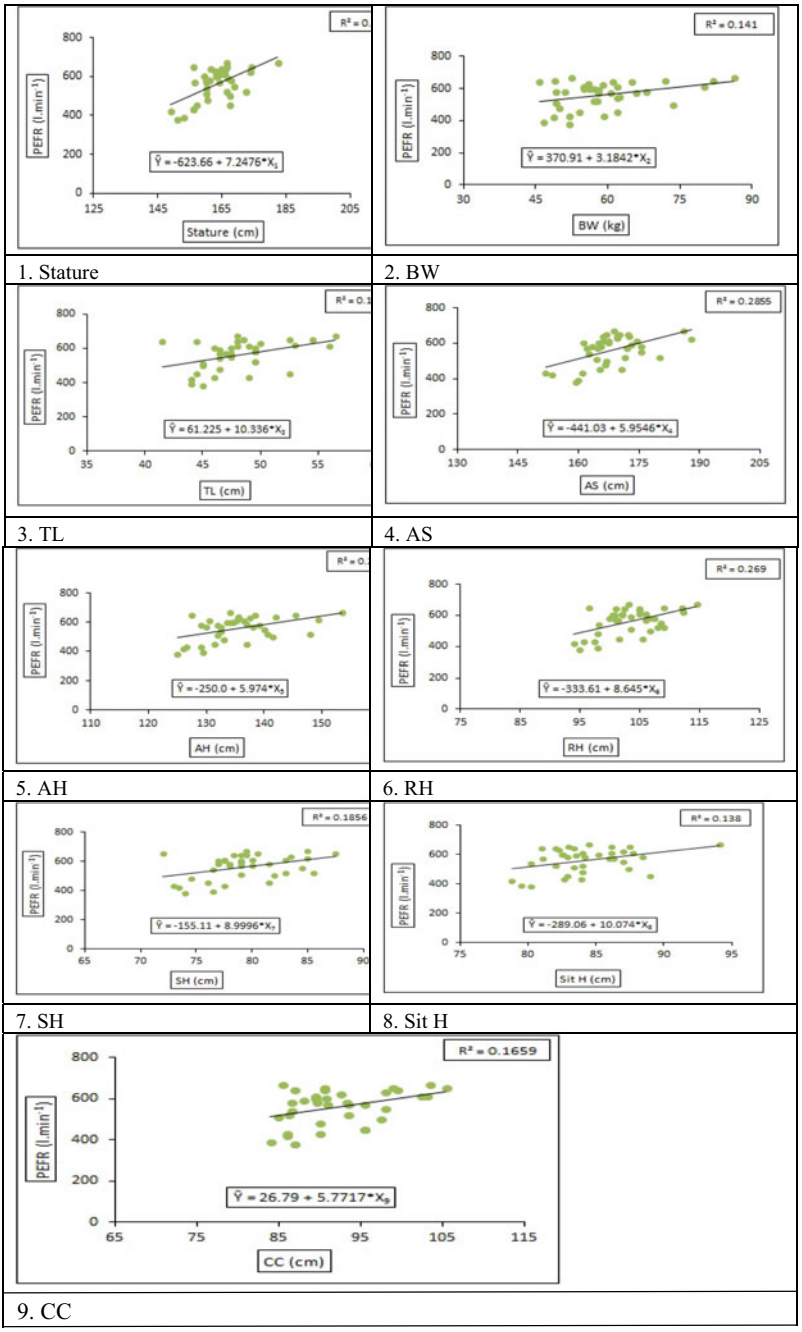


Fig. 2 Graphical representation of regression equations for estimating indicator of pulmonary function (PEFR) utilizing select surrogate markers as predictors 1. Stature, 2. BW, 3. TL, 4. AS, 5. AH, 6. RH, 7. SH, 8. Sit H, and 9. CC

Table 4 Multiple regression equation for estimating pulmonary function indicator (PEFR) using the most important anthropometric variables as predictors in SG individuals

Anthropometric variables (predictor)	Lung function indicator (criterion)	Regression equation	F value	*P* value
Stature in cm (X_1)	PEFR ($l.min^{-1}$)	$\hat{Y} = -648.579 + 5.860*X_1 + 1.497*X_4$	9.247	0.001
Arm span in cm (X_4)				

Table 5 Background particulars of the VG individuals

Parameters	Values
Age (years)	30.9 ± 5.56
Working experience (years)	10.2 ± 5.21
$SBP_{Pre\ work}$ (mm Hg)	128.9 ± 11.90
$DBP_{Pre\ work}$ (mm Hg)	86.0 ± 8.87
$HR_{Pre\ work}$(beats min^{-1})	83.3 ± 12.67

AM ± SD

Table 6 Anthropometric variables and PEFR of VG individuals

Parameters	Values
Anthropometric variables	
Stature (cm)	163.3 ± 6.39
Body weight (kg)	59.6 ± 9.33
Trunk length (cm)	48.3 ± 3.39
Arm span (cm)	167.9 ± 7.25
Acromion height (cm)	135.5 ± 6.12
Radial height (cm)	103.4 ± 4.69
Stylion height (cm)	79.6 ± 3.78
Dactylion height (cm)	60.3 ± 3.74
Sitting height (cm)	84.5 ± 3.08
Chest circumference (cm)	92.6 ± 5.72
Waist circumference (cm)	84.8 ± 8.75
Hip circumference (cm)	92.4 ± 6.34
Body mass index (kg m^{-2})	22.3 ± 2.52
Body surface area (m^2)	1.64 ± 0.14
Lung function indicator	
Peak expiratory flow rate ($l.min^{-1}$)	562.3 ± 77.97

AM ± SD

4 Discussion

Along with increased urbanization and simultaneously to meet the excessive demand, the wood processing industries has been growing extraordinarily in the recent years. Therefore, the number of small units engaged in maintenance and repair of wooden works have increased manifold and so in the number of human resources involved therein. Being unorganized/informal in nature, the working hours/weekly holidays etc. is also virtually non-existent. At times the human resources do stay in such hazardous workplace leading to a definite prolongation of the exposure period. The PEFR values obtained is 559.5 $l.min^{-1}$ (Table 2) in individuals who are exposed in wood dust, the value is lower compared to their age and sex-matched control counterparts [20]. Present finding is in agreement with the values reported from a study conducted on male wood processing workers of central India [21]. Additionally, it is the fact that the functionality of the lungs is not only affected by several kinds of environmental factors but also by some biological issues [22–24]. Furthermore, surrogate markers in term of anthropometry, basically deals with the human body dimensions related to lung functioning. By performing, Pearsonian correlation, it is found that there is significant ($P < 0.05$) positive linkage present between select anthropometric variables and PEFR. From Fig. 1, it is observed that PEFR has a significant ($P < 0.05$) positive linkage with select surrogate markers-stature, body weight, arm span, trunk length, acromion, radial, and stylion height, sitting height, chest circumference and body surface area. The body weight in the present study is also having a positive linkage with PEFR; the present findings are in agreement with earlier reports carried out on adult male individuals [25–27]. BSA, a function of both stature and body weight, has been found to have significant positive correlation with PEFR (r value = 0.46; $P < 0.05$) (Fig. 1). The findings are corroborating an earlier study from middle-east India [28–30]. It is reported that stature, one of the reliable predictor of pulmonary functioning showed strong positive association (r-value: 0.59) with PEFR in the present study [24, 31–33]. But for the purpose of prediction of lung function values from stature, non-distorted height is mandatory and any kind of physical disability, neuromuscular hindrance, leg amputation etc. in such cases, arm span will give the estimate of stature [16, 33–36]; however, in this current study, arm span has been measured and a significant ($P < 0.05$) linkage with PEFR has been noted. The sitting height has also a significant ($P < 0.05$) positive relationship (r-value: 0.37) with PEFR. In fact, different types of airways obstructions like restrictive, obstructive, and or combined obstructions dependent not only upon the compliance of the lungs but on the chest wall also [31, 37, 38]. Hence, trunk volume has a great impact on the functionality of the lungs. And, chest circumference, as well as trunk length both, have a significant positive linkage with PEFR [17]. Similarly, there is also significant ($P < 0.05$) correlation found between the anthropometric parameters like AH (r value = 0.47), RH (r value = 0.52), SH (r value = 0.42), and PEFR, the indicator of pulmonary function (Fig. 1). The results are in consonance with earlier studies conducted on male individuals involved in different occupations living in parts of Sri Lanka, Argentina and Baghdad, Iraq

[25, 36, 39]. Post establishing the significant correlation, the mathematical model to predict pulmonary function indicators from select anthropometric parameters has been developed (Table 3) along with the graphical representations of the models (Fig. 2). Subsequently, all the developed models have been validated with age, gender and ethnicity matched validation group. A similar attempt has been made in finding out the correlation between anthropometric parameters like stature with pulmonary function indicator PEFR in earlier studies conducted on young males of Jamshoro [37]. In the present study, it has been found that the developed regression equations have strong test–retest validity. In addition, F values of all the mathematical models showed significance at the level of $P < 0.05$. Based on the highest correlation, found between surrogate markers-tature (cm) (r value: 0.59) and arm span (AS) (cm) (r value: 0.53) and PEFR, multiple regression model has been developed and presented in the Table 4 and it has also been found that the developed multiple regression model have strong test–retest validity. The study wanted to highlight that an estimate of pulmonary function in remote locations can also made at least cost without requiring costly instruments, work dislocation etc., and in the process the study suffers from a limitation that it does not include several other pulmonary function indicators that need use of expensive instruments.

5 Conclusion

It may be concluded from results presented and discussed that the regression model developed on the basis of significant positive correlation found to exist between the anthropometric variables, used as surrogate markers, and the lung functional status indicator; the model has been and subsequently validated, It may be used for making estimation of likely values of pulmonary functionality indicator-PEFR; this definitely surmounts the requirement of expensive spirometers and recurring costs of performing the tests at cost by visiting laboratories at a distance resulting in loss of man-days and earnings on the part of the human resources. This study hence has potential of being used for making initial idea about the functional status of lung that is likely to be affected for being exposed to compounds present in wood dust in course of occupational engagement for days in and days out, and hence can be of use in facilitating occupational health particularly from human factor perspective.

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Effects of Built-Environment Attributes on Workplace Psychology and Productivity

Nivia Jain

Abstract There is continuous interaction between humans and built-environment and hence it affects humans. Humans experience the built-environment through their senses and since it is created by us, it becomes imperative to design it consciously. *Objective*: To study the impact of the built-environment on the comfort, well-being, and productivity of humans in workplaces. Work environment plays a very crucial role as it affects mood, happiness, wellbeing, and performance of its inhabitants. It's said that finding right place to live and work can greatly help with improving happiness. Architecture has the power to allow or inhibit humans to act, behave and think. This research attempts to analyze the relationship between human productivity and architecture and how built-environments can limit/enable humans. *Methodology*: The study identifies key physical parameters affecting human productivity by compiling and analyzing various research done in the past 30 *years.* The impact of identified parameters has been further studied by conducting two primary case studies. One compares the built-environment of two offices of a national daily and compare it with the self-assessed productivity and satisfaction levels, keeping variables like work culture constant. Further, an open survey has been conducted with 110 respondents to draw correlations. Analysis has been done using basic social statistical tools including methods of correlation and regression. *Findings* It has been observed that the built-environment does impact human productivity. Thermal comfort, lighting, perceived health and hygiene, ergonomics, basic building amenities, aesthetics, and ease of work have been found to have a significant impact on perceived productivity.

Keywords Productivity · Workplace · Built-environment · Comfort · Wellbeing

1 Introduction

Urban dwellers spend up to 90% of their time indoors [1]. They are in a continuous engagement with the built environment, either they are inside or around it. Humans

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engages with the built environment through its senses, through visual, tactile, auditory, olfactory and even gustatory stimulus, this experience could be positive or negative depending on the feeling invoked in humans through it. Since built environment is man-made, these stimuli can be controlled to ensure that buildings do not have a negative impact on humans and instead assist to promote their health and well-being.

Productivity and performance of employees have a major role to play in any human resource dependent organizations. Work environment provided to the employees can affect their mood, well-being, and performance. It is said that finding the right place to work and live can substantially improve general happiness [2]. Architecture has the power to influence how humans act, behave, think, and reflect. This study attempts to analyze the effects of the built-environment attributes on employee productivity and sense of wellbeing.

1.1 Relevance

As human resource costs substantially high as compared to the other costs incurred by an organization, investing in providing the ideal working environment can be effective in ensuring high productivity. Since built environment can affect many people, the impact might be small to each occupant, but the overall performance of the occupants can be significant. Even a small negative impact of the work-environment on the employee can result in a cumulative high loss of productivity for the organization. A study by Rosenfeld [3], suggests that an additional investment in the climate systems of 10% in each office situation is justified if it results in a productivity increase of even a 0.33%. Though this percentage will be hardly measurable, it does indicate the relatively significant effect of the productivity aspects on the cost effectiveness of an additional investment [4].

1.2 Theoretical Framework

Productivity. The Merriam-webster dictionary meaning of "productivity" (noun) is - the state of being productive, especially in industry, as measured in terms of the rate of output per unit of input. Other popular definitions include—Productivity is output per hour, considering quality [5]. Productivity is the increased functional and organizational performance, including quality [6]. Human productivity when talked about in the workplace is the level of performance from employees within the organizational constraints [7]. Productivity could be measured under three criteria's: (1) Ability to think analytically (2) Ability to think creatively (3) Ability to collaborate [8].

Well-Being and Productivity of Humans. Productivity of humans is closely linked to their wellbeing. One can be most efficient in one's work when one's body is equally efficient and there is peace of mind. There is a direct relationship between personal wellness and productivity. Wellness can be understood in 5 aspects—Physical, mind, energy, knowledge and bliss. Supporting each of them can lead to increased effectiveness at work and in life, whereas feelings of depression, stress or anxiety may lead to a lost sense of purpose or meaning. [9] As per WHO—"Human health is defined as a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."

Humans and the Built Environment. All human actions occur in a physical space. Architecture not only assist daily human functioning but also affect how we feel and act. It may influence a person's mood, decisions, health, and behavior. Though one must be cautioned that individual differences are likely to lead to varied experiences of the same space. Our environment interacts with us through stimuli. It stimulates our senses—and consequently our bodies react to it. Our body's reaction to this stimulus depends on the kind of stimulus it receives, and the hormones released as its result. Since most of the times these stimuli are generated by the built environment surrounding us, these can be controlled to some extent and so can, indirectly, our reactions to them. Stimulation theories consider the physical environment as a crucial source of sensory information [10]. Sensory information from a built environment may be simple like color, sound, light, noise, temperature or complex like a whole building, part of a locality etc. [11].

Work-Place Environment. Any environment that is used for work is a workplace environment. Often people from different castes, culture, gender, age, and physical abilities together compose a workforce and have different working environment requirements. Any workplace environment is composed of both the physical environment as well as the social environment. A conducive physical environment can often assist forming a conducive social environment hence architecture or interiors can have a role to play in creating and fostering a work culture.

Relationship Between Workplace Environment and Productivity. The Hawthorne Effect [12] theorizes that improved environmental conditions would positivity correlate to increased worker productivity. A person's satisfaction with the work environment has a direct impact on an employee's satisfaction which has a direct relation to an employee's productivity and is influenced by perceived levels of privacy, freedom, and control.

1.3 Human Environment Relationship Theories

Control Theory. Having a sense of control over our surroundings is important to our wellbeing. James Averill talks about having 3 kinds of control over our environments: (1) Behavioral control—the ability to change the environment. (2) Cognitive

control—the ability to change the way in which we perceive an environment. (3) Decisional control—the ability to choose a reaction. Personal control is often conceived as having both the freedom of action and the level and type of stimulation to which humans are subjected to. humans' feeling about the environment is directly affected by the actual or perceived control over their environment. "Most people can adapt to various levels of stimulation and attempt to establish personal control using cognitive mechanisms of personal space and territoriality" [13].

Behavioral Setting Theory. Some behaviors are considered acceptable in specific environments but not in others hence behavior must be studied in its natural context. These behavior settings are small-scaled systems composed of social and physical infrastructure arranged in a way to carry out routine actions within a specified time and location. Most behavior settings are public environments which have the following three components: (1) physical properties, (2) social components, (3) environment setting. Research shows that behaviors can indeed be activated by environmental cues without conscious thought [13].

Stimulation Theory. Humans reacts to sensory stimulation. Examining the different levels of sensory information deriving from an environment can help to assess that environment's level of stimulation. Senses can be over-stimulated (hyper-stimulated) or under-stimulated (hypo-stimulated) and hence the threshold of the stimulation becomes important. Once getting used to a certain level of stimuli, humans no longer consciously notice it until it changes. Human's level of perception often dictates how much the stimulation must change before it is noticed. Theories that help to explain the relationship between stimulation and human behaviors include the arousal perspective, environmental load or overstimulation, and adaptation. As per the arousal perspective, the environment itself causes an auto-nomic physiological response like increased heart rate, blood pressure, respiration, adrenaline secretion, and neural activity within the brain. Optimum arousal is an important factor in learning and productivity. While over arousal can lead to cognitive chaos, under arousal can lead to inaction or even apathy. Design cannot affect arousal directly but can serve to modify stimulation levels that affect arousal.

2 Methodology

2.1 Personal Parameters Affecting Employee Productivity

Comfort. Comfort is the absence of unpleasant sensations, which has a positive effect on wellbeing and productivity. In work environment, comfort corresponds to a state of being—free from pain and poised for optimal productivity. A space that is a little 'uncomfortable' can help keeping employees more alert as it breaks the neutral comfort state. Hence variations in the ambient environment can become controls for productivity.

Absenteeism. Absenteeism can be due to various factors—organizational, personal, sickness, psychological, and is a key deterrent to productivity.

Stress. There could be various triggers for stress—Physical environment, social environment, personal. Employees with high levels of stress tend to have lower engagement, are less productive and have higher absenteeism. Physical environmental factors like—noise, temperature, lack of comfortable furnishings or illumination can all add to the work-related stress there by reducing employee satisfaction.

Job Satisfaction. Determined by how well employee's job meet their work expectations, an employee's physical environment has a direct impact on its job satisfaction. Job satisfaction is positively correlated to employee's wellbeing, life expectancy and is negatively associated with stress, anxiety, and low self-esteem.

Motivation. Motivation within the workplace has a direct relation with employee productivity. Employees who are motivated about their work carry out their responsibilities to the best of their ability and have favorable results.

Sick Building Syndrome. Sick building syndrome is a serious problem. It is a collection of various illnesses related to respiratory problems, headaches, fatigue, chronic coughing and overactive sinuses, chronic eye, nose, and throat irritations which get triggered due to unhealthy stimuli from the built environment.

2.2 Physical Parameters Affecting Employee Productivity

Lighting. 87% of the sensory information through which humans experience its surrounding is through light [14]. It regulates the circadian rhythm in humans which controls our mood, alertness, sleep, and concentration in response to the light that is received and has a direct impact on the productivity and indirectly affects the—immune system, recovery, memory and behavior. Human centered lighting works towards enhancing human performance, health, comfort and overall wellbeing. Light affects human—(1) Performance, (2) Preference, (3) Perception, (4) Impressions, (5) Behavior and (6) Mood. All these variables have a relation with human productivity. Light stimulates humans through two pathways

Visual pathway. Which supports the visual performance and visual experience. It helps humans to see, experience the way around us and perform.
Non-visual pathway. Supports the acute system and circadian system. It takes care of the biorhythm and health along with making them alert and perform. Optimal support of the two pathways creates psychological comfort. According to Veitch, people who appraise the lighting as good will also appraise their space to be more pleasant, be more satisfied with the work environment, and more engaged in their work [15]. Higher illuminance levels can result in feelings of increased alertness and better performance.

Sound Level. Sound affects us behaviorally, psychologically and cognitively. Humans constantly process sound, consciously or unconsciously. It affects human's alertness and concentration levels. Unnecessary sound/noise takes up a significant part of the brains rendering humans unable to concentrate and thereby increasing probability of errors. Distractions caused by sound in a work environment can contribute to reduced productivity by as much as 66% [16]. Noise also has an impact on human wellbeing as it contributes to stress, increased blood pressure and heart rate. Sources of sound can be internal or external. External sounds may include noise due to traffic, public, machinery etc. Internal noise may include co-employee conversations, machine/system noise e.g., telephones, office equipment, HVAC systems. Acoustic strategy considers both internal noise factors and external noise factors for effective management.

Thermal comfort. ASHRAE (2004) defines thermal comfort as the condition of mind which expresses satisfaction with the thermal environment. Parameters like—temperature, humidity, speed of air movement, clo-factor, and metabolic rate controls thermal comfort. Except metabolic rate, all others are physical environment factors which can be controlled. According to Adaptive Comfort Theory, people may not report any change in productivity on change of temperatures provided they have adapted sufficiently to maintain comfort levels. But a higher level of dis-comfort can have a drastic impact on productivity [17].

Air Quality. Poor Indoor Air Quality (IAQ) influences the occurrence of respiratory illnesses, allergy and asthma symptoms, and sick building syndrome symptoms. Poor IAQ involves various components, physical pollutants like particulate matter, biological pollutants like bacteria, high VOC levels and CO levels etc. These pollutants have a severe impact on health, higher VOC and CO levels might trigger headaches and irritability among employees, while physical and biological pollutants might induce acute respiratory problems. This impact on health leads to higher absenteeism and hence lower efficiency and productivity.

Level of Control. When humans get to make a choice, they feel more empowered. Level of control is to what extent does the employees get to control their environment. This can be broken down into—(1) Level of control over seating—Ability to choose their seat and environment to work. (2) Level of control over thermal conditions—More control over thermal conditions, results in a higher average thermal comfort, as employees with different metabolic rates and clo factors can regulate the conditions to their preference thereby creating a more comfortable environment. (3) Level of control over lighting—Ability to regulate the lighting conditions, need for light might vary from person to person due to factors like age, eyesight or the level of intricacy associated with the work. Though level of control might not have a significant impact physically, but it can boost employee morale, leading to happier and satisfied employees resulting in better productivity.

Aesthetics. Beautiful or pleasing work environment can make employees feel happier and more satisfied, remain more motivated and hence productive. Things like art works, installations etc. can act like eye strain relievers and help uplift moods.

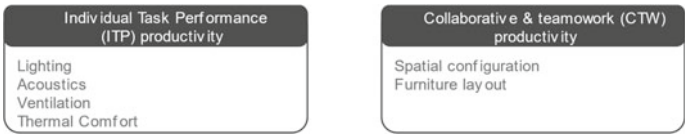


Fig. 1 Two levels of work performance

Employees when remove their eyes from the screen, the long-distance view should have something pleasing to offer which automatically refreshes the mind.

2.3 Measuring Productivity

Productivity can be defined as the ratio of output to input. When measuring employee productivity, this evaluation is difficult as the output or input is not quantifiable most of the times, especially in knowledge intensive organizations. Hence other models have been adopted. Work performance is measured at 2 levels—Individual Tasks productivity (ITP) and Collaborative and Teamwork productivity (CTW). As shown in Fig. 1, certain physical factors affect the productivity of these task categories. Both productivity types can be analyzed according to positive and negative parameters. Positive measures of productivity include faster, accurate output, effective employee retention, efficient decision making. Negative measures of productivity include absenteeism, illness, employee turnover, complaints. An effective work environment counters these effects.

2.4 Theoretical Models Used to Measure Productivity

A combination of these models has been used to measure productivity through a survey and observation method.

User Satisfaction Model. It uses surveys to question users about their likes/dislikes of any environmental features, about their satisfaction with their workplace, and if they prefer an existing or future environmental feature.

Employee Motivation model. It not only considers the effects of environmental factors on behavior, but also elaborates on a variety of influences on employee motivation. "The physical environment is identified to have a unidirectional effect on employee motivation, when the physical setting was appropriate to the task, employee motivation is not affected, however when the physical set-up is not suited for the task, it slows down work, it has a 'demotivational' effect on employees" [18].

Comfort Model. "Cause for discomfort is subjective and varies from individual to individual. However, it is possible to identify some common factors that are

perceived as unpleasant for most people" [19]. Comfort model was developed to devise operational definitions and guide empirical studies of employee-workspace relationship. According to the model, users require physical, psychological, and functional comfort to use their environment to perform their tasks well; a comfortable environment provides comfort at all 3 levels. These experiences of comfort are amendable to objective measurement and can be compiled to provide a reliable measure of environment's effectiveness. The comfort model can be visualized as a pyramid. In Fig. 2 This pyramid shows that physical comfort is foundational for the other two categories of comfort. The boundary value suggests the level of comfort one should not fall below, as below this point dis-comfort hampers usability.

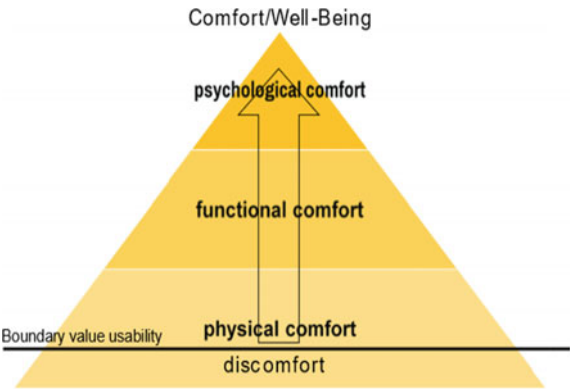
Physical comfort is in most cases taken care of by building standards that covers all the areas affecting user's physical comfort like light levels, sound absorption ratings. When employees identify a physical comfort problem, it tends to have a negative effect on their perception of all other workspace features. These may include Protection and Security, Light and illumination, Indoor air quality, Climate, Noise, ergonomics.

Psychological comfort primarily includes sense of territoriality, both individual territory (workspace, office) and group territory (team workspace). Sense of privacy, and control are fundamental aspects of territoriality, and that people define themselves and their work in part according to their criteria. The social and spatial parameters may include—Privacy, Crowding, Territoriality, Status, Control over the environment.

Functional comfort. It is the effectiveness of the space in enabling users to complete their tasks. It Is not guided by individual preferences or needs but is based on generic requirements of tools to work. Functional comfort requirements become more important and complex with the increased complexity of tasks involved (Fig. 3).

These methods are subjective and are not based on any quantitative data and relies on individual's own subjective assessment. For this study, subjective productivity measurement has been used to evaluate employee performance.

Fig. 2 Comfort model



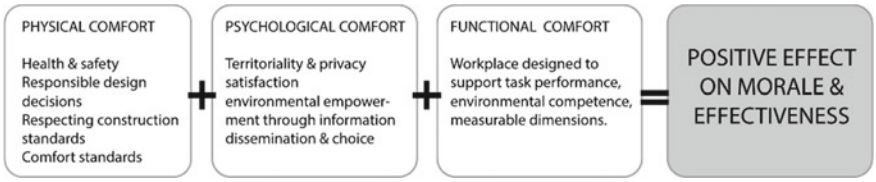


Fig. 3 The comfort equation

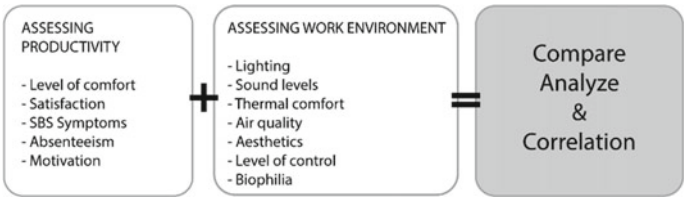


Fig. 4 Methodology for testing productivity

2.5 Testing Parameters

Since employee productivity is subjective and not quantifiable. Perceived productivity analysis has been adopted, which is a self-assessment approach, the questionnaire asked the employees to rate certain parameters based on how they perceive it. Since how we think is directly related to how we perform, the results achieved through this process have minimal deviations. The survey included two parts: (1) Assessing productivity and (2) Assessing work environment (Fig. 4).

3 Analysis

3.1 Secondary Study Results

Various studies have been done to understand the relation between environmental parameters and productivity, mostly under controlled environments, a compilation and analysis has been made to identify the factors that have a significant impact on productivity which have been taken up for further analysis in the Indian context.

The parameters identified based on 30 independent studies are—(1) Sick building syndrome symptoms, (2) Indoor air quality, (3) Thermal comfort, (4) Level of control, (5) Daylight, (6) Noise levels.

3.2 Primary Case Study

Criteria for selection (1) Corporate work environment (2) Minimum of 50 employees (3) Two offices of the same company to make the work culture constant (4) Significant difference in the work environment in the two offices.

Two offices with distinct work environments of a leading national daily has been taken to evaluate the impact of work environment on the perceived employee productivity, keeping the work culture and kind of work constant. One of the offices (Noida office) is relatively new, based on good design practices ensuring proper light and ventilation. Other office building (Chandigarh Office) is relatively old with little consideration to good built environment practices. Along with comparing survey results from these offices, an open survey has also been conducted including assessment of perceived productivity and assessment of work environment. 110 employees of knowledge-based organizations have taken part in the survey which has been used to derive insights.

Survey format was adapted from the survey devised by Vischer [20] Surveys have been conducted in their natural behavioral setting to maintain the accuracy of the answers.

Table 1 Comparison of means of the two offices

Parameter	Chandigarh office	Noida office
Control over heating, cooling and ventilation	4.10	6.20
Control over lighting	4.87	6.23
View of outdoors from work place	4.87	5.13
Greenery and open areas around office	4.43	5.70
Lighting	5.13	6.03
Perceived health and hygiene	4.60	5.57
Furniture/ergonomics	4.00	5.93
Access to basic building amenites	3.67	5.70
Interiors	4.87	6.37
Ease of work	4.93	5.33
Satisfaction with physical environment	5.00	6.20
Productivity	4.40	5.67

Means are out of 7

3.3 Results and Analysis

A significant difference has been found in the perceived productivity and satisfaction levels of the employees in the two offices. Employees at the Noida office have significant control over lighting and thermal conditions while employees at the Chandigarh do not. There is a considerable difference in the satisfaction with lighting levels of the employees, it can be validated by the poor lighting conditions observed at the Chandigarh office with nearly no access to natural light whereas special consideration has been given to provide optimal lighting in the Noida office with access to natural daylight to almost all the spaces in the office (Table 1).

A correlation analysis was conducted to understand the relation among different parameters and correlations with factors greater than 0.75 were further analyzed using scatter graphs and regression (Fig. 5).

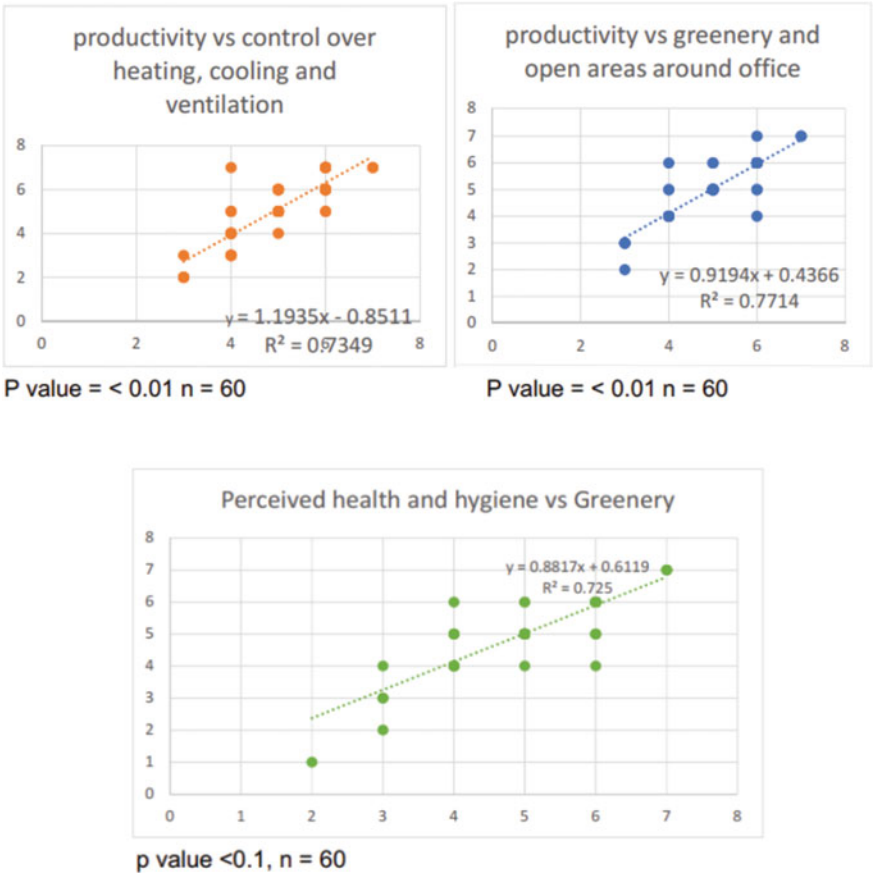


Fig. 5 Correlation of productivity with environment parameters

It can be concluded that level of control over heating, cooling and ventilation, presence of green areas around the office, ergonomic work friendly furniture and access to building amenities are significant contributors to the perceived productivity of employees of the organization. Further, a strong relation between Perceived health and hygiene and presence of greenery around has been noted.

A similar analysis has been drawn from the open survey and has been observed that thermal comfort, lighting (specially in summers), perceived health and hygiene, comfort of furniture (ergonomics), basic building amenities, aesthetics and ease of work impact perceived productivity significantly, it is important for employees to feel satisfied with their built environment to perform their best, be efficient and more productive.

4 Conclusion and Way-Forward

It is observed that the built environment does have a psychological impact on humans and thus impact human productivity. Since a lot of factors contribute to human experiences, impact of individual variable does not have a significant measurable impact but the cumulative of all the physical parameters can have a significant impact over perceived human productivity. The most significant parameters that came out of the research are thermal comfort, lighting (specially in summers), perceived health and hygiene, ergonomics, basic building amenities, aesthetics and ease of work. There is a strong relation of biophilia with perceived health and hygiene which indirectly impacts human productivity, issues with open office layout have been observed, though most widely adopted layout, employees complain of high noise levels, lack of conversation and visual privacy and is perceived to be a deterrent to their productivity. Four key points have been repeatedly observed, employees wish for biophilia, natural daylight, bright colored interiors and basic building amenities. Today a lot of importance is being given to energy efficient design and sustainability, it is high time that along with this we start focusing on human centric design, design for the human experience and human wellness. There is need for conscious design with these factors in mind to achieve a better, more productive built environment. Autodesk Toronto tech center is one such example where generative design tools have been used to design the workplace considering such parameters, it used computational design and generative workflow to optimize the objectives and create a workplace that takes into consideration the preferences of each of the 250-plus employees who work there.

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Ergonomic Evaluation of Workstation Components in Work from Home Settings During COVID -19 and Its Correlation with Musculoskeletal Symptoms: A Self-Reliant Approach

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Abstract Covid-19 has mandated work from home and has brought to focus more personal responsibility towards health and working environment. This is a bigger challenge considering the dearth of knowledge on ergonomics and resources for an appropriate work-station set-up. The sudden rise in the reported musculoskeletal discomfort is consistently described in various recent studies. The early intervention strategy may be to identify the lacuna in the work setting by making individual self-reliant in evaluating their respective work-stations. This study was conducted with an objective to document self-evaluated computer workstation components in work from home settings and correlate these findings with reported musculoskeletal complaints. A cross- sectional survey was conducted using Google form structured using guidelines from "Computer Workstation Ergonomics: Self-Assessment Checklist by the National Institutes of Health, Office of Research Services, Division of Occupational Health and Safety website and Nordic pain questionnaire, used to identify the musculoskeletal symptoms. 238 people volunteered and completed the survey form. A significant negative correlation was observed between Computer Workstation Ergonomics: Self-Assessment Checklist scores and VAS score ($r = -0.386$, $p < 0.01$), and with areas of discomfort ($r = -0.292$, $p < 0.01$). Work-related musculoskeletal discomfort at work from home settings is associated with inappropriate design, non-availability of peripherals to fit the work station and simpler adjustments as reported via structured self evaluations by workers. Active self-reliant worker empowered to address ergonomic needs could be a valuable strategy during the pandemic.

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Keywords Work-related musculoskeletal discomfort · Self-evaluation · Work from Home · Ergonomics · Covid-19 · Self-reliant approach

1 Introduction

Global Covid-19 (Coronavirus Disease -19) spread in the first quarter of 2020 was declared as a pandemic by WHO. The nationwide lockdown enforced in India to mitigate the spread of virus mandated the shift of work from office spaces to home environment [1]. Work from home is referred to as working from a remote location and where the employees do not have to commute to a central and single place of work. It is also called telecommuting and remote work. This shift from office to home was quite rapid with no warning or opportunities for preparation with personal health and work safety becoming growing concerns. Understandably, these initial makeshift home-offices served dual or multiple functions, and hardly comply to ergonomic recommendations, posing a risk of Work-related musculoskeletal discomforts [2]. This problem can predictably be of higher scale in a country like India where IT professionals demonstrate lesser mindfulness and compliance to ergonomics, resulting in musculoskeletal discomfort reports [3–5]. Existing reports on WRMSD's from India suggest a prevalence ranging from 58 to 69% before the onset of the pandemic while recent statistics show an upsurge up to 71% [5–8].

Ergonomics is the scientific study of human work, intending to obtain an effective match between the user and work station to improve comfort and ease of working, enhancing efficiency, health, and safety [9]. An ergonomically deficient workplace may not result in immediate pain, however, in time, the compounding effect of job and/or workplace deficiencies will surpass the body's coping mechanisms, causing the inevitable physical symptoms, emotional stress, low productivity, and poor quality of work [10]. Understanding the needs of workers is primary as it creates an opportunity to identify the problem area early and seek the necessary help to set up a supportive and controlled work environment. Such proactive measures enable workers to function in safe work environment and thereby having better efficiency and job satisfaction while simultaneously curbing known ergonomic risk factors. Proactive ergonomics pave way towards a successful outcome and is a more cost-effective way to improve performance, health, and well-being rather than reactive ergonomics [11]. Therefore, implementation of ergonomics at workplaces is irrefutably desirable. WFH is a fresh scenario that begs considering these principles as inclusive parts of work culture in India. Guidance into adapting to remote online work is an absolute necessity and available literature reviews from many sources and articles reveal that setting a good ergonomics regime is extremely beneficial to both employers' prospect and employees' health [12].

In the current situation of the pandemic enforced work from home module, we may not achieve a direct one -on -one evaluation and advice owing to social distancing norms and quarantine measures but can narrow this gap by guiding the computer users to self-evaluate their work station using workstation checklists. This approach

is intended to fill the lacuna of non-availability of personal professional help instead, make a computer user self-reliant and empowered to assess and incorporate essential modifications. Also, this allows to a better understanding of workers' perspectives based on one's self-appraisal of the work area using structured methods and also helps generate understanding of coexisting problems and their association with reported shortcomings.

Self- evaluation checklists are a quick and simple way to evaluate and assess the utilities and usability of elements of a workstation system/ interface. A wide range of ergonomic checklists are available in literature with considerable positive performance in terms of inter-rater reliability and predictive validity [13, 14]. In terms of resources, checklists are one of the quickest techniques to train, practice, and apply. Broadly, there exist two general classes of ergonomics checklists: Analysis Checklists and Action Checklists [15]. Analysis Checklists are more suitable to perform an analysis of a system or product while Action Checklists are more appropriate for tasks in finding practical improvements in products or systems. Computer Workstation Ergonomics: Self-Assessment Checklist by the National Institute of Health (NIH), Division of Occupational Health and Safety [16] is a standard, reliable tool for self-evaluation of computer workstations and a resource that is utilised in this study. This research was conducted with objectives to document self-evaluated computer workstation components in work from home settings and study the correlation of these findings with reported musculoskeletal complaints and pain. The study also intended to gather responses with respect to certain work setting parameters via a set of open-ended questions.

2 Methodology

This survey was conducted in May 11th to June 30th 2020 when the lockdown was in its initial phase and processes were irrefutably shifted to work from home with a decision to promote WFH as a most likely forthcoming option for IT workers. This study was conducted using an exploratory framework and a correlational design.

It was conducted online using survey questionnaire, designed specifically to collect information and to identify the deviations from the recommended work position in work setup in WFH, using questions from NIH- 'Computer Workstation Ergonomics: Self-Assessment Checklist' [16].

Standardised VAS scale [17] and Nordic pain questionnaire [18] were used to collect the information on pain and discomfort at various body parts experienced by the workers which they attributed to work. The questionnaire was prepared using Google form with the anonymity enabled option and the link was shared on e-mail which had to be completed using Google platform. The first section of the survey requested the demographic details; the second section had 24 questions on work station settings as per NIH—Self-Assessment Checklist for computer workstation ergonomic risk assessment and the third section enquired regarding musculoskeletal discomfort using questions based on Nordic musculoskeletal questionnaire.

The participant information introduced volunteers regarding purpose of study by stating the following clause "Purpose of this study is to document the self-evaluated computer work station findings and to see if there exists a correlation between self-evaluated computer work station scores and self-reported work-related discomfort. The collected data will be maintained anonymously and will be utilised only for research work without disclosing your personal information and details. Your participation in this study is completely voluntary and if you feel yourself uncomfortable answering any question, please feel free to skip the question. This survey will take 20 min of your time. The completed and a submitted survey will be considered as your consent to participate in the survey". At the end of the survey, a set of open-ended question queried for their responses or their experiences about work from home. The primary researcher contact details were shared to solve queries if any.

In this study the inclusion criteria were individuals using computer for the purpose of work for more than 6 h per day and at least 5 days a week. This study was conducted as per the guidelines of the national and international regulations, and the Declaration of Helsinki (2000). Complete information about the study requirements was provided to the participants and with permission of data sharing and privacy policy participation data was gathered in the study. Participants' personal information, including names, was kept anonymous to protect confidentiality. Completed, questionnaire was transferred to the Google platform and the final data was downloaded on Microsoft Excel sheet. Statistical analysis was done using SPSS 20.

3 Results

A total of 238 computer users working from home participated in the survey of which 22% were women and 78% were men. The participants had mean age of 33 ± 4.95 and mean Body Mass Index of 25 ± 3.95 with average working hours of 7.9 ± 0.785. The demographic profile is displayed in Table 1.

Out of the respondents who described symptoms of pain and discomfort, the reported areas /body parts on Nordic Questionnaire varied from 1 to 9 areas with mean of 2.1 ± 1.6. The mean pain score on VAS scale was found to be 4.5 ± 2.1.

All the participant in this survey reported using laptop for their work. The NIH—Self-Assessment Checklist which has questions about work station components with yes and no choices was scored with Yes score as 1 and No as 2. Our survey respondents' score varied between 3 and 24 with the mean score of 12 ± 5.03.

The association between the NIH- Self-Assessment Checklist scores with VAS pain scale scores (Table 2) and Areas of discomfort (Table 3) analysed using Spearman's Correlation coefficient showed a significant negative correlation $r = -0.386$ and $r = -0.292$ respectively. These findings are suggestive of an association that exists between improper work station design with increased reports of musculoskeletal discomfort with respect to the body areas as well as severity of experienced pain/ discomfort intensity.

Table 1 Demographic profile of participants (N = 238)

Demographic profile	Number (n)	Percentage (%)
Gender		
Female	52	22
Male	186	78
BMI (Mean = 25.36 ± 3.95)		
<18.5	7	3
18.5–24.9	97	41
25–29.9	103	43
30–30.9	30	13
>40	1	–
Hours of computer use (Mean = 7.9 + 0.785)		
6–7 h	85	36
7–8 h	90	38
>9 h	63	26

Table 2 Correlation of NIH-Self-Assessment Checklist score with VAS scores

Correlation			NIH checklist score
Spearman's rho	VAS Score	Correlation Coefficient	-0.386^{**}
		Sig. (2-tailed)	0.000
		N	238

** Correlation is significant at the 0.01 level (2-tailed)

Table 3 Correlation of NIH-Self-Assessment Checklist score with Nordic Questionnaire- Areas of discomfort

Correlation			NIH checklist score
Spearman's rho	Number of areas of discomfort	Correlation Coefficient	-0.292^{**}
		Sig. (2-tailed)	0.000
		N	238

**Correlation is significant at the 0.01 level (2-tailed)

The participants also responded to a few open-ended questions regarding salient components of their respective work station set up like seating arrangements, provision for back rest, laptop placement and use with or without modifications, overall lighting and ventilation in their work from home set-ups.

The summary of responses and experiences are listed below.

- 18% of participants reported that they were using standard office chairs with adjustable height, seat and backrest and that their feet were fully supported on

the floor while working. 25.6% reported using plastic chairs and 19.3% used wooden chairs while 15.5% used their beds and 12.2% used sofa to be seated while working. Smaller percent of participants also reported to be using couches or sitting on the floor for work.

- 67% said they use some sort of back support while working irrespective of their type of seating arrangement. Overall, only 38.8% felt that their seating arrangement was comfortable at home work set-up
- While all the participants used laptops, 52.5% mentioned using them without any modifications and usage of peripherals like external keyboards; mouse or monitors were reported by the other 47.5%.
- 46.2% of respondents managed to set the screen height of the laptops or monitor screen to their eye level.
- On further enquiry about lighting and ventilation a greater percent of participants i.e., 94.9% and 91.5% respectively reported well-lit and ventilated work areas at home.

4 Discussion

Work from Home (WFH) may be seen as a "New Normal" and a "Virtual" method of functioning amidst the current unprecedented state of the on-going pandemic [2]. This has resulted in increased screen times and spending longer demanding hours at poorly designed makeshift work environments. The ergonomic principle of "fit the workplace to the worker" is barely met and this almost always in known to hasten the onset of bodily discomforts and is counter-productive for efficiency [5].

The critical components of work and the design of work stations in home set ups are variable and uniform recommendations may not be feasible. Enabling a worker to best assess his work station using simpler accessible tools may be the way forward which also disseminates greater awareness and brings in the concept of "Participatory Ergonomic Approach" into these work from home set-ups [11].

The present study was designed with the approach of inducing self-reliance in knowing one's work place, risk factors and understand the possible association of these aspects with most frequently reported musculoskeletal discomforts. NIH- Self-Assessment Checklist used in the current study was reported useful to help maintain wellbeing, safety and maximised performance by respondents in a recent survey [13] and we also find usage of this tool to be easy, with important tips related to key workstation areas.

While it is known that poorly designed work stations contribute to musculoskeletal pain [19] a make-shift home setup may only add to this effect. We found a vast majority of workers reporting substantial pain/discomfort in one or many body areas and this calls for early measures to be incorporated in order to be able to fulfil the demands of the current circumstances. Though the sample size is relatively limited the result makes it evident that that there exists a significant correlation between

ergonomically ill- fit work stations and increased reported number of areas of discomfort and pain. Hence making recommendation to address this issue could be a likely step looking ahead.

This is one of the earliest studies done with a renewed outlook towards WFH workers in India. The data was remotely collected, based on an individuals' self-evaluation and scoring. Though this method lacked professional evaluation of work stations and/or provisions for confirmatory assessment, we recommend using this method for preliminary understanding of one's own work arrangements in a structured manner and awareness for utilising resources available for self-help, self-reliance of checking one's work position and work station components in their own environment. Results of a study done to assess the accuracy and feasibility of NIH–CWC checklist suggest that an expert using the self-reported NIH–CWC combined with workstation photographs can accurately identify mismatches between workers and their computer workstations [20]. Therefore, fairly accessible tele- assessment and consulting, with image/video guided methods and their effectiveness may be explored. It is amply clear that a once desired, highly favourable 'work from home' has not proved to be one of the best options for majority of IT workers in India. This option needs to be researched further with a view of physical and mental health of such workers. Better guidelines to properly regulate work from home, making it a feasible alternative should be done on priority.

5 Conclusion

In conclusion we may comment that there are significant deficiencies in work station components in WFH set up and are not up to the mark or ergonomically appropriate for working long hours.

The self-assessment scores showed significant correlation with musculoskeletal discomfort and pain complaints and goes on to highlight the necessity of such employee inclusive, empowered approach to self-assess the work place and understand its relevance to work related Musculoskeletal discomforts.

Such proactive participation may improve the overall outlook in terms of being aware of risk of injuries, seek active modifications and usage of resources, improve work efficiency and organizational productivity.

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User Survey of UPI-Enabled Payment Apps

Siddhi Chavan, Praduemna Gore, and Ganesh Bhutkar

Abstract This research paper suggests some measures that the app developers/designers of these Payment Apps can adopt to further improve the user experience and enlarge the user base of these apps. This research paper presents the results of a user survey of Unified Payments Interface (UPI)-enabled Payment Apps in India. It studies various aspects related to the most popular top five online Payment Apps used in India namely—Google Pay, PhonePe, Paytm, Amazon Pay and Bharat Interface for Money (BHIM). The main goal of this user survey is to find the usage patterns of these Payment Apps. Another important goal of this survey is to identify the most popular Payment App in India and analyze the reasons behind its popularity. This survey attempts to know the reasons for a significant population not using Payment Apps. The respondents were presented with a questionnaire with 18 questions. The survey, which was conducted online using Google Forms received a total of 228 valid responses and it covers a wide range of age groups which are (18–30), (30–45), (45–60) and 60+ years. Both male and female respondents have been included in the survey. The findings of the survey suggest that Google Pay is the most widely used Payment App in India and these apps are most popular among the younger age group of (18–30) years. This research paper also suggests some measures that the app developers/designers of these Payment Apps can adopt to further improve the user experience and enlarge the user base of these apps.

Keywords User survey · Payment Apps · UPI · India · Google Pay · PhonePe

1 Introduction

India is emerging as a huge digital market in the world. According to McKinsey Global Institute's 'Digital India Report 2019', India's digital adoption level rose by 90% between 2014 and 2017 which is the second fastest among 17 major digital economies [1]. The last decade has triggered the momentum of the digitisation process with the digital payment system setting its foot. According to the Reserve

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Bank of India (RBI), the growth of mobile cellular network infrastructure, increasing smartphone usage and cheaper internet in India are major enablers of digital payments [2]. The demonetisation of November 2016 [3] and the COVID-19 pandemic [4] enforced a behavioural change in the digital payments trend.

There are several modes of digital payments available in India today—Mobile Wallets, Debit/Credit Cards, Unified Payment Interface (UPI) and others. The National Payments Corporation of India (NPCI) launched UPI in 2016 [5]. UPI allows you to make instant real-time money transfers between different bank accounts. Unlike Mobile Wallets, the UPI app eliminates the concern of transferring money between the Wallet to the bank and vice versa. Instead, it directly debits and credits amounts into your linked bank account. As of Dec. 2020, there are 207 banks supporting UPI platform [6]. Each bank has a per UPI transaction limit and a daily UPI transaction limit [7].

Mobile apps like Google Pay, PhonePe, Paytm, Bharat Interface for Money (BHIM), Amazon Pay, MobiKwik have enabled UPI payments by scanning Quick Response (QR) codes or by using the mobile number of the person one wants to pay. Banks like State Bank of India (SBI), ICICI, HDFC and other banks also provide UPI-enabled Mobile apps for their consumers.

The introduction of the UPI platform made way for the big giants to enter the digital payments field. BHIM was founded and developed by NPCI in 2016 which supports only UPI transactions [8]. Following this development, PhonePe owned by Flipkart went live in 2016 [9]. Digital payment platform Paytm is an Indian multinational technology company founded in 2010. Paytm offers services for prepaid mobile, DTH recharge, bill payments and digital wallet. Paytm introduced payments using BHIM UPI on its platform in 2017 [10]. Google launched UPI enabled Tez payments service in 2017 [11]. Tez folded into Google Pay in 2018. Amazon Pay was launched as an online payment processing service in 2007 by Amazon. Amazon Pay—the UPI enabled Payment App was launched in India in 2019 [12].

Figure 1a–e shows the logos of the UPI-enabled Payment Apps. UPI has witnessed record high transactions in contrast to the gloom cast by COVID-19 and lockdown across the economy [13]. To stay in the race, Payment Apps have started offering discounts, cashbacks, rewards to woo the customers. E-commerce websites like Amazon, Flipkart, Zomato and others have enabled Payment Apps to link to their Payment Gateways. New feature in-app charity donations are being added. Not much research work is available studying how familiar and satisfied customers are with

Google Pay	PhonePe	paytm	amazon pay	BHIM
(a) Google Pay	**(b) PhonePe**	**(c) Paytm**	**(d) Amazon Pay**	**(e) BHIM**

Fig. 1 Logos of UPI-enabled Payment Apps

these features in the Payment Apps. This observation has been a motivation for survey with Payment apps and following are the major objectives of this survey:

1. Understand the patterns and issues pertaining to online Payment Apps and help the respective companies to understand their clients effectively and,
2. To identify the most popular Payment App in the Indian market and understand the reasons behind its popularity. The five most popular Payment Apps—Google Pay, PhonePe, Paytm, Amazon Pay and BHIM have been selected for this user survey [14].

2 Related Work

Following are a few research papers dealing with user surveys with Payment Apps.

Tripathi et al. [15] made a study on adoption of digital payment through payment application with reference to Gujarat State of India in 2020. A survey was conducted for the study with about 100 respondents from various corners of the country. Majority of respondents lie between the age of 21 years to 25 years. The study concluded that respondents preferred mobile payments due to convenience, cashbacks and discounts, quick transactions, detailed records of spending and reduced security theft. Majority respondents are satisfied with the mobile payment application. This study helped in understanding the motivation of people for using mobile payments.

Sayed et al. [16] made a study on customer satisfaction level and perception of e-payment app services with special reference to Pune City in 2018. The study made a comparison of Paytm, BHIM, MobiKwik and PhonePe by conducting a survey with 200 respondents. It was concluded that Paytm was the most widely used Payment App in Pune with a market share of 74%. Payment Apps from private sector companies work more in advance to the public sector app BHIM. The respondents of the survey were satisfied with the discounts and quick payments offered by the mobile Payment Apps. However, the respondents were not fully satisfied with the safety and security features of the Payment Apps. This study helped in identifying the popular app among Paytm, BHIM and MobiKwik in Pune and also the popular discounts feature of the Apps.

Khan et al. [17] conducted a survey with about 100 respondents to understand the frequency of usage and the problems faced while using e-payments and examine the effects of e-payments contribution towards sustainability of business growth. The behaviour pattern of consumers towards purchasing and utilising products and services is altered by giving the consumers options like variety, discounts and payment preferences. This has exposed consumers towards habitual use of browsing products and using different online payments helping products and/or payment platforms gain customer loyalty. This study helped in understanding the increasing importance of e-payments in e-commerce or business activities and the issues of security and privacy.

Gupta et al. [18] studied three Payment Apps—Google Pay, PhonePe, Paytm. The study concluded that Google Pay is highly preferable for making high value

transactions as it makes payment directly from the bank account of the users as compared to PhonePe and Paytm. These Apps have more or less the same features, but they differ on parameters like Wallet Facility, Security and Languages supported. It was also concluded that in order to increase the user-base of Payment Apps, security features need to be added. This study has helped to identify the most popular Payment App—Google Pay and the factors used to compare the Apps.

Singh et al. [19] discussed factors affecting customer satisfaction with respect to Paytm and BHIM Payment Apps. The study depicted that there are differences in private and government platforms on providing services which affects customer satisfaction. The analysis indicated that there is a need to involve factors like intention to use, innovation and discount-offers which attract individuals and derive insights on strategies like security, multi-functionality and other automated features to gain customer loyalty. This study helped in understanding some of the reasons behind less popularity of BHIM App as compared to private sector Apps.

A few vital observations are made during the literature survey. Users prefer Payment Apps due to convenience, quick transactions and cashbacks and discounts. Average number of participants involved in a user survey with Payment Apps is about 100. Users are more concerned with features such as app security and privacy. Rising popularity of Payment Apps has contributed to the e-commerce industry. It is observed that BHIM App has less popularity as compared to private sector Payment Apps.

3 Methodology

3.1 Questionnaire Design and User Sampling

During this user survey, we designed a structured questionnaire, consisting of a total 18 questions divided into 3 sections, which the respondents were directed to, based on their responses. The first section of the survey included questions related to demographic information of the respondents such as gender, age, occupations and annual family incomes. The respondents were then directed to the second or the third section depending on whether they use Payment Apps or not. Using the random sampling and snowball sampling methods [20], a set of 228 responses was collected which consisted of users who used one or more of the Apps or did not use any Payment Apps at all. Some of the questions that we asked include:

1. Which Apps do you use and how often?
2. For what purposes, do you use these apps the most?
3. Rank the benefits of the App you use the most.
4. Provide reasons behind not using Payment Apps.

The apps for the survey were chosen based on the popularity of these apps in the Indian market and these apps were Google Pay, PhonePe, Paytm, Amazon Pay and BHIM.

3.2 Data Collection and Analysis

Considering the current global COVID-19 pandemic situation, it was decided to conduct the survey through an online method using Google Forms. The analysis on the responses was performed on parameters like the age, popularity of the apps, their purpose of usage and features and benefits of these apps. Respondents of the survey are mostly from Pune city of Maharashtra state in India. Tables 1, 2, 3, 4 and 5 depict

Table 1 Respondents of the user survey using Payment Apps

Respondents using Payment Apps	Respondents not using Payment Apps	Total respondents
201	27	228
88.16%	11.84%	100%

Table 2 Gender of the respondents of the user survey

Male respondents	Female respondents	Total respondents
142	86	228
62.28%	37.72%	100%

Table 3 Age group of the respondents of the user survey

18–30 year	30–45 year	45–60 year	60+ year	Total respondents
113	55	54	6	228
49.56%	24.12%	23.68%	2.63%	100%

Table 4 Occupation of the respondents of the user survey

Occupation	Number of respondents	Percentage of respondents (%)
Student	102	44.74
Service/working professional	70	30.70
Business	28	12.28
Homemaker	13	5.70
Self employed	12	5.26
Agriculture	3	1.32

Table 5 Annual family income of the respondents of the user survey

Upto Rs. 5 lakhs	Rs. 5 lakhs to Rs. 10 lakhs	Rs. 10 lakhs and above	Total respondents
63	83	82	228
27.63%	36.40%	35.96%	100%

Table 6 Usage of Payment Apps by respondents

Only one App used	More than one Apps used	Total respondents
41	160	201
20.40%	79.60%	100%

Table 7 Age group of the respondents of the user survey using Payment Apps

18–30 year	30–45 year	45–60 year	Total respondents
104	49	43	196
53.06%	25%	21.94%	100%

the demographic information of the respondents such as number of app users, gender distribution, age groups, occupations and annual family incomes.

4 Survey Results

4.1 Usage of Multiple Payment Apps

Among the 88.16% users who make use of Payment Apps, majority of the users have registered on more than one Payment Apps, as seen in Table 6.

4.2 With Respect to Age Groups

The number of Payment App users decrease gradually with increase in age, as seen in Table 7.

4.3 Reasons for not Using Payment Apps

About 12% of the respondents of the survey do not use Payment Apps. 12 of the respondents state the reason “Don’t feel safe”. 18% of respondents are not comfortable using the technology. One respondent states “In India, digital platform is not

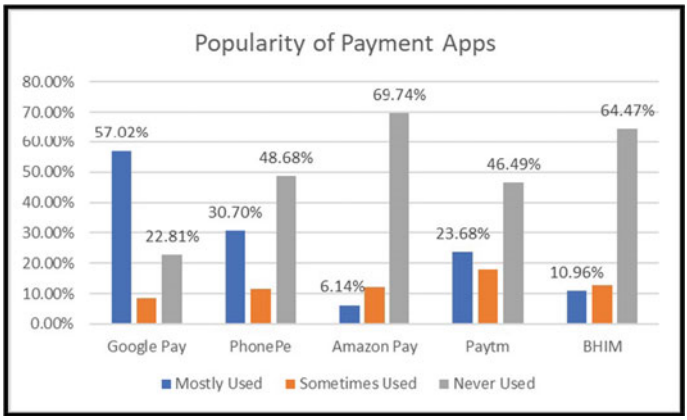

Fig. 2 Bar graph comparing popularity of Payment Apps among the users

available everywhere". Almost 75% of the respondents not using any Payment Apps say that they should start using these Apps in the situation created by the corona pandemic.

4.4 Popularity of Payment Apps

Figure 2 shows Google Pay, Paytm and PhonePe are popular among the users with Google Pay winning the race. Amazon Pay and BHIM were 'Never Used' by 69.74% and 64.47% users in the survey. Google Pay is followed by PhonePe, Paytm, BHIM and Amazon Pay respectively in that order.

4.5 Purpose for Using Payment Apps

More than 50% of the users make use of the Apps for buying daily essentials, bill payments and recharge and money transfer to family/friends/colleagues. About 48% users do online purchases and about 13% users use these Apps for business activities.

4.6 Opinion on Features

More than 60% of the users in the survey find the Payment Apps easy to use and were satisfied with the success rate of transactions. However about 43% of the users feel the need to improve "Cashbacks and Rewards", about 13% of the users feel the

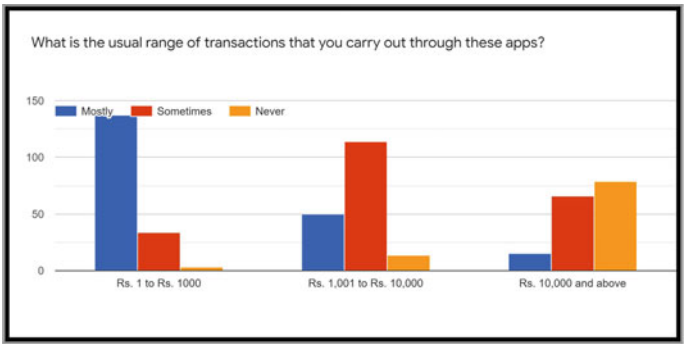

Fig. 3 Bar graph showing usual range of transactions carried out by the users through Payment Apps

need to improve "Successful Payments" and about 29% of the users feel the need to improve "Support during frauds" in the Payment Apps.

4.7 Usual Range of Transactions

Figure 3 shows that about 69% of the users mostly carry out transactions in the range of Rs. 1 to Rs. 1000 through these apps. Only 7.5% users use it mostly for transactions of Rs. 10,000 and above, despite the transaction limit for most of the apps being Rs. 1,00,000.

4.8 Micro-credit (Small Loans) Facility

About 72% users think that Payment Apps should probably provide a feature for small loans.

4.9 Participation in In-App Donation and Charity Initiatives

Almost 50% users don't participate in any in-app donation or charity initiatives.

4.10 Linking to E-Commerce Apps

24.37% users said that they never link their Payment Apps with any e-commerce apps/sites like Zomato, Amazon or Flipkart. They even cancel the order if there is no other option available.

4.11 Knowledge of UPI Transaction Limit

Almost 40% of the users are unaware of the daily UPI transaction limit and transaction limit per transaction. More than 70% of the users are satisfied with the UPI transaction limit provided by their bank.

5 Discussion

Google Pay emerged as the winner amongst the Indian users of Payment Apps in the survey. Google Pay is followed by PhonePe, Paytm, BHIM and Amazon Pay respectively in that order. These Payment Apps are easy to use and convenient to carry out transactions.

Google Pay has focused only on simple money transfer directly into bank accounts and has no digital wallet option which is offered by Paytm and PhonePe. This eliminates the concern of transferring the money between the digital wallet and the bank. The success of Google Pay attributes to the user experience and the product strategy. People value the feeling of "How the app made me feel". The sense of joy received from the celebratory tick mark after a successful payment as shown in Fig. 4a and the scratch card gamification for cashbacks/rewards shown in Fig. 4b makes the user want to carry out the next transaction on Google Pay. Users develop a trust in the products which celebrate their culture. The targeted campaigns on Indian festivals as shown in Fig. 4c and events help in building user engagement. Google Pay also

(a) Celebratory tick mark | **(b) Scratch Cards** | **(c) Indian festival offer**

Fig. 4 Google Pay user experience strategy

introduced the "Tap and Pay" feature which enables payments without using QR codes making it more convenient.

BHIM app developed by NPCI has limitations to what it can offer compared to the other companies [21]. BHIM loses the race in customer life-cycle—first stage: user adoption, second stage: engagement. Less incentives lead to decline in user adoption and less features lead to a decline in user engagement. Users look at Amazon as more of a shopping site than a Payment App which impacts their reach to the most recently launched Amazon Pay app. Further the COVID-19 lockdown and social distancing norms impacted the ability to onboard new offline merchants as well as perform in-person Know Your Customer (KYC) for Amazon Pay wallet customers [22].

Cashbacks and rewards are a tried and tested system to enlarge the user base. Payment Apps like Google Pay, PhonePe and Paytm used the cashbacks system aggressively in the initial days of the launch. Users register on multiple apps to try and avail various offers from different apps. However, cashbacks have seen a decline after Payment Apps like Google Pay gained a place in the market [23]. 43% of the users in the survey feel the need to improve the cashbacks/rewards system in Payment Apps.

"Trust" is the most important factor when making payments through digital platforms. Indians trust Google followed by Paytm, Amazon and Flipkart according to a report by Forrester in 2019 [24]. Brand trust develops consumer loyalty. The rate of successful transactions is determined by the server of the Payment Service Provider (PSP) bank which is collaborating with the Payment App. Google Pay, PhonePe, Amazon Pay and BHIM have collaborated with PSP banks whereas Paytm is using its own—Paytm Payments Bank as the PSP. According to NPCI, the success rate of transactions of the Paytm Payments Bank is the highest among all the other PSP banks [25]. The user traffic on these apps also influences the success rate of transactions. Since Google Pay and PhonePe are the most used apps, the success rate of transactions is comparatively less than Paytm, BHIM or Amazon Pay.

In case of charity, people usually prefer to donate where they can witness the end-usage of their money. The Payment Apps do not display any information about how much money was raised, where exactly it was used and how it benefited the target population. Transparency regarding charity initiatives will develop trust among the users. Addressing cyber security issues will increase confidence in people to participate in in-app donation activities, to link their Payment App to e-commerce sites and to carry out transactions involving high amounts of money.

Users are found complaining about the "pending" status of transactions in Google Pay, which is stuck for three to five days. There is no option to cancel these pending transactions which might be successful or might fail [26]. PhonePe checks the receiver bank's UPI network, and doesn't allow the user to carry out any transaction until the connection gets restored. Figure 5 illustrates PhonePe's way of reducing the error rate caused by UPI network slowdown.

Almost 40% of the users in the user survey are unaware of the UPI transaction limit of their banks. No Payment App displays the daily UPI transaction limit of the

Fig. 5 PhonePe minimizing transaction failure

user's bank. Provision should be made to display the UPI transaction limit in order to reduce the error rate of carrying out transactions more than the limit.

Users responded positively to include the feature of small loans in the Payment Apps considering the changing trend of attitude towards new credit sources and increasing 'consumerism' as users now require credit for satisfying even their daily requirements.

'Retrieval of money after wrong transactions' remains a contentious issue among all the UPI enabled apps, since a successful UPI transaction cannot be reversed. The money, if transferred to a wrong account, can only be retrieved if the receiver himself returns the amount [27]. This might be the reason for 30% users being unsatisfied with support provided by these apps during frauds. BHIM app allows users to block unknown 'money requests' to prevent the users from falling prey to scams [27]. Google Pay flags a UPI account in red colour if the UPI ID has been reported by other users. NPCI has incorporated stringent controls to protect its systems from cyber threats [28].

6 Limitations and Future Scope

Opinions of Indian users from rural regions and other states of India were not recorded. Respondent bias is visible with respect to the age and occupation of the respondents. This paper has a scope to analyse the opinions of users who use the payment apps for their business. User experience of each of the five Payment Apps can be studied in detail in future. Apart from UPI transaction facility, digital wallets provided by the Payment Apps like Paytm and PhonePe can be studied further.

7 Conclusion

The survey findings clearly suggest that the popularity of Payment Apps has increased in recent years due to the convenience and ease of use they offer. It was observed that people who are not using these apps currently are also inclined towards using them in the near future. Given the demographic dividend of India, these apps still have a tremendous potential of growth in the Indian market. **Among the most popular**

Payment Apps, Google Pay has won the top position owing to its publicity, user experience design strategies and trust among the users. Google Pay is followed by PhonePe, Paytm, Amazon Pay and BHIM respectively in that order. Google Pay needs to address the concern of error rates caused by "pending" transactions and a rise in transaction failures [28]. PhonePe overcomes this error rate by refusing payments if any internet connection issue is observed on the sender's mobile device or on the receiver's bank server. Providing a warning during poor internet connectivity significantly reduces the error rate. **Cashbacks/rewards** which are used to attract the customers in the initial days of the launch needs to be improved along with the security of the app. Enhancing security and generating awareness among the users will develop consumer loyalty. Ensuring transparency of charity donations received, will increase user participation in **in-app donation/charity initiatives** through the Payment Apps. **A critical suggestion to all the Payment Apps would be to display the transaction limit to the users on the screen where the user enters the amount for transactions**. The success of UPI in India can be a great case study for the developed economies, which are still hesitant to adopt Quick Response (QR) code payments at a large scale. If the concerns of people not using these apps are appropriately addressed by the companies along with some policy help from the government, UPI payments can provide another 'feather in the cap' for the 'Digital India' programme.

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Experience of Cognitive Workload During In-Vehicle Distractions

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Abstract Drivers' ability to capture driving related information, interpretation and timely action upon that information determines safe driving. However, the cognitive resources of the driver to perceive, interpret, and execute driving related information are limited. The limitation of cognitive resources brings the issue of cognitive workload in focus. In the light of this understanding, the current study examines in-vehicle object and spatial distractions in terms of their effect on cognitive workload experienced by drivers. 47 drivers voluntarily participated in this test-track study. Equal number of drivers were randomly assigned to in-vehicle object and spatial distraction conditions. Drivers assigned to object distraction condition had to process object appearance information whereas under spatial distraction they had to process spatial information. After the completion of the drive, each driver's cognitive workload was assessed by using National Aeronautics and Space Administration-Task Load Index (NASA-TLX). It was observed that there is a significant difference between in-vehicle object and spatial distraction with respect to their effect on cognitive workload. The results indicate that the drivers experienced more cognitive workload during object distraction. Multiple regression analysis of cognitive workload reveals that temporal demand, effort, and performance dimensions are significant predictors of overall cognitive workload, but the other three dimensions (i.e., mental demand, physical demand and frustration level) are not. Further, the stepwise analysis of the

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dimensions of NASA-TLX showed that temporal demand is the most dominant factor which contributed to 85% of the cognitive workload experienced by the drivers.

Keywords In-vehicle distractions · Cognitive workload · Distracted driving · Working memory

1 Introduction

The task of driving consists of the interaction of the driver with the vehicle (i.e., driver–vehicle interaction) in a highly dynamic environment. Several factors determine the complexity of driving environment which include road design (i.e., highways vs. city roads vs. rural roads), road layout (i.e., straight roads vs. curvy roads, roads with junctions vs. no junctions), and traffic density (i.e., high vs. low). Another factor is that with every passing year, there is an increase in the smart features embedded in the vehicles (in terms of internet enabled navigation, entertainment and communication features). These devices have a high potential of distracting the driver and negatively affecting his/her responsiveness towards driving related activity. In the context of India, the number of vehicles on Indian roads has increased by 200% from 2007 to 2017. There is also an increase in the number of registered vehicles per 100 km of Indian roads. The number has increased from 2408 in 2006–07 to 4286 in 2016–17 [1]. This indicates that there is more congestion on the roads and would keep increasing with every passing year as new vehicles keep continuously come on the roads. In comparison to this, the cognitive resources of the driver to perceive, interpret, and execute driving related information are limited.

The limitation of cognitive resources brings the issue of cognitive workload in focus. The mismatch between the demands of the driving situation and the limited availability of cognitive resources is a major concern for traffic safety. Cognitive workload imposed by a task or multiple tasks will depend on the cognitive resources called upon. Cognitive workload is a multidimensional construct which is concerned with the ability of an individual to meet the information processing demands imposed by a task [2]. It involves at least two major components: input load and individual's effort. Input load consists of the environment and task demands placed on the individual. The load on the individual is his/her reflection to the input load in terms of the efforts. Thus a common analogy of workload is often drawn with physical load broadly comprising stress (task demand) and strain (the resulting impact upon the individual) [3]. When the task demands increase, an individual invests more resources voluntarily to keep the performance at an acceptable standard. A high workload restricts the individual's performance in the interaction with the system [4]. Performing multitasks normally require more resources than a single task and may cause overload easily [5]. The workload experienced by one person may be different from that of another person's experience.

An efficient tool for assessing cognitive workload has two important properties: (a) sensitivity (ability to discriminate between different levels of cognitive workload) and

diagnosticity (ability to distinguish different types of workload) [6]. The purpose of measuring cognitive workload is to identify and also eliminate the factors responsible for performance decrements [2]. The methods of gauging cognitive workload can be classified broadly under 3 categories: (a) subjective measures, (b) performance measures, and (c) psychophysiological measures. These methods can be used either singly or in a combined form- to make assessments of cognitive workload depending upon suitability and/or feasibility of the study.

Subjective measures require the participant to determine the amount of work required to complete the task. The most commonly used method for such measures are rating scales [example, Cooper-Harper Scale, Bedford Scale, NASA-TLX]. Performance measures generally involve assessment of performance of primary and secondary tasks. Such measures are based on the parameters of speed and accuracy of performance [6]. With the technological advancement, there are numerous psychophysiological measures employed by the researchers in workload measurement. These include, electroencephalography (EEG), evoked related potentials (ERPs); magnetic evoked potentials (MEPs); electrodermal response; eye movements, etc. [6].

1.1 Driving and Cognitive Workload

Complex traffic situations and high cognitive workload are one of the leading contributing factors to road traffic accidents [7]. Recarte and Nunes [8] reported that the complexity of driving situation narrows down attentional focus size and subsequently lead to more driving errors. According to American Association of State Highway and Transportation Officials [9], with an increase in the amount of information to be processed, there is an increase in drivers' reaction time for performing a relevant driving maneuver. They also reported that as the reaction time increases, there are higher chances for driving errors. Several studies have investigated variations in cognitive workload and the associated effects on driving errors [10, 11]. They examined cognitive workload as a function of traffic flow and road layout. Their results revealed that an increased traffic flow is associated with an increased cognitive workload and performance impairments.

While driving a vehicle there are many factors that could potentially trigger cognitive workload [12]. The day by day increase in traffic density and the introduction of new in-vehicle information systems (IVIS) pose new demands to the driver [13]. In the context of driving, when there is an increase in the situation complexity (e.g., high traffic flow, intersection, etc.), the cognitive workload increases, which consequently would result in road accidents and near accidents. The demand supply relationship of cognitive resources would form the state of overload, underload, and optimal state. It is observed that non-professional drivers experience higher cognitive workload and consume more cognitive resources [14] and have 2–4 times higher accident rates than their professional counterparts [15]. For an excellent driving performance,

drivers should experience optimal driving workload which is correlated with driving experience [7].

2 Design

The current study used a 2 × 2 between-subjects design. The first independent variable, (i.e., in-vehicle distraction) was manipulated in terms of object versus spatial distraction and the second independent variable, (i.e., expertise) was manipulated in terms of novices versus experts. In order to operationalize expertise for this study, Chi's relative approach [16] was used. According to this approach, experts are relative to novices on the continuum of expertise. This approach also states that expertise develops as the operator spends more time in a particular task domain. In the current study, a driver is considered an expert if she/he has a driving experience of three or more years [17]. An instrumented vehicle (Volkswagon POLO, 2015 Model, Hatchback 1.2 petrol highline, right hand drive) was used for collecting the data. The distracting stimuli (i.e., object and spatial distractions) were presented to the driver from her/his left side through a display monitor (DELL Inspiron laptop with 360 degree rotatable screen). A suction based monitor holder was used to hold the display monitor.

Participants. Participation in this study was voluntary**.** This study is based on the participation of 47 drivers (46 males and 1 female) who were recruited from the surrounding educational institutes including the institute of one of the authors itself. After initial scrutiny, data from 7 participants was found to be invalid. Expert drivers ($N = 20$) mainly consisted of the drivers of buses of educational institutes and their conductors were recruited as novice drivers ($N = 20$). Novice drivers also consisted of the PhD students of the authors' educational institute. The age range of expert drivers was 23–48 years ($M = 33.45$; $SD = 7.74$) and a mean score of 12.10 years' driving experience. With respect to novice drivers, the age range was 20–34 years ($M = 26.95$; $SD = 3.56$) and a mean score of 2.32 years' driving experience.

Procedure. The participants were given a brief introduction of the experimental task that they had to perform while driving. After the introduction of the task, informed consent was taken from each participant.

In-vehicle object and spatial distractions were presented to the drivers through a display monitor which was attached to the windshield. After the completion of the drive the drivers were asked to report the cognitive workload that they experienced. The cognitive workload was assessed by using an android based NASA-TLX application. For more details about NASA-TLX, please see Paxion et al. [18]. Initially, the basic identification details about the participants were filled in by the researcher and the participants were then asked to rate each of the six dimensions of NASA-TLX according to the cognitive workload they experienced while driving during in-vehicle object and spatial distractions.

3 Results

For determining statistical significance, an alpha level of 0.05 is used. IBM SPSS Statistics (version 22) was used to analyze the data. A two-way ANOVA was used to examine the effect of in-vehicle distraction and expertise on the overall cognitive workload of drivers. As shown in Fig. 1, in-vehicle object and spatial distraction vary significantly with respect to their effect on overall cognitive workload of drivers. The statistical analysis revealed a significant main effect of in-vehicle distraction, object ($M = 62.730$) and spatial ($M = 50.663$) on cognitive workload, $F(1, 36) = 17.349$, $p = 0.001$, $\eta p^2 = 0.325$. With respect to expertise also, a significant main effect was observed, novice ($M = 67.923$) and experts ($M = 45.470$) on cognitive workload, $F(1, 36) = 60.071$, $p = 0.001$, $\eta p^2 = 0.625$ (see Fig. 1). However, no interaction effect was shown by the analysis $F(1, 36) = 1.135$, $p = 0.294$, $\eta p^2 = 0.031$.

In order to examine which of the six dimensions of NASA-TLX have significantly contributed to the overall cognitive workload, a multiple regression analysis was performed. By using the enter method of multiple regression, a significant model emerged: $F(6, 33) = 66.196$, $p < 0.01$. The model predicts 90.9% of the variance (Adjusted $R^2 = 0.909$). Table 1 provides information of the predictor variables entered into the model. Temporal demand, effort, and performance dimensions are significant predictors of overall cognitive workload, but the other three dimensions are not.

In order to identify the proportion of variance contributed by NASA-TLX, a deeper analysis of cognitive workload was performed. As shown in Table 2, temporal demand emerged to be the most dominant factor which contributed to 85% of the cognitive workload variance, $F(3, 36) = 138.126$, $p < 0.01$. Adjusted $R^2 = 0.913$. Temporal

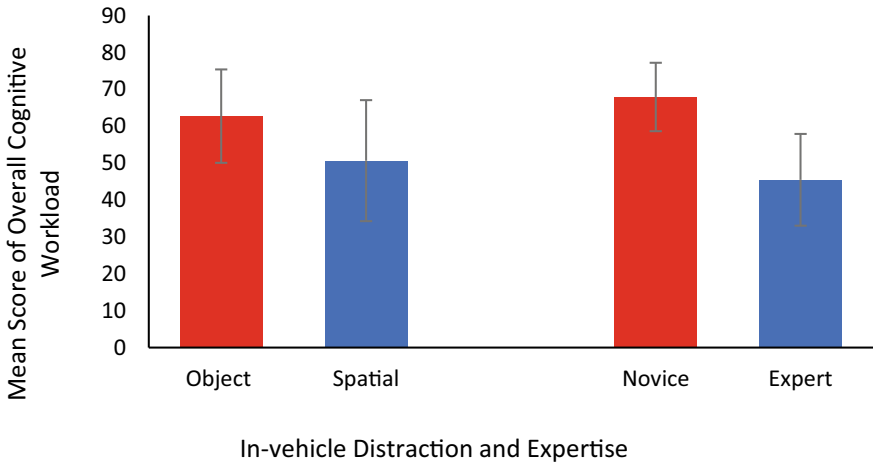

Fig. 1 Overall cognitive workload as a function of in-vehicle distraction and expertise. Error bars denote *SD*

Table 1 The unstandardized and standardized regression coefficients for the variables entered into the model (enter method)

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	1.376	7.673		0.179	0.859
	Mental demand	23.711	21.894	0.058	1.083	0.287
	Physical demand	−0.003	0.075	−0.002	−0.036	0.972
	Temporal demand	0.466	0.063	0.651	7.394	0.000
	Performance	0.102	0.043	0.161	2.387	0.023
	Effort	0.248	0.055	0.439	4.548	0.000
	Frustration	0.031	0.078	0.029	0.400	0.692

Table 2 Model summary of dimensions which significantly contributed to variance in cognitive workload (stepwise method)

Model	R	R^2	Adjusted R^2	SE of the estimate	Change statistics				
					R^2 change	F change	df1	df1	Sig. F change
1	0.926[a]	0.857	0.854	6.00551	0.857	228.570	1	38	0.000
2	0.952[b]	0.906	0.901	4.93519	0.049	19.270	1	37	0.000
3	0.959[c]	0.920	0.913	4.62028	0.014	6.216	1	36	0.017

[a]Predictors: (constant), temporal demand
[b]Predictors: (constant), temporal demand, effort
[c]Predictors: (constant), temporal demand, effort, performance

demand, $\beta = 0.854$, $p < 0.01$. Effort, $\beta = 0.049$, $p < 0.01$. Performance, $\beta = 0.014$, $p < 0.01$. Table 3 shows the coefficients of regression.

4 Discussion

This study was undertaken with the intention of examining how is cognitive workload of drivers affected by their expertise and in-vehicle distraction. With respect to in-vehicle distraction, the results show a significant difference between object and spatial distraction in terms of their effect on cognitive workload experienced by drivers. The drivers reported that they experienced more cognitive workload during object distraction as compared to spatial distraction. The reason for more cognitive workload during object distraction is that a mechanism of verbal coding is used by working memory for processing the object related information (i.e., information

Table 3 Summary of regression coefficients for dimensions which significantly contributed to cognitive workload (stepwise method)

Model dimensions		Unstandardized coefficients		Standardized coefficients
		B	Std. error	Beta
1	(Constant)	16.370	2.831	
	Temporal demand	0.663	0.044	0.926
2	(Constant)	18.219	2.365	
	Temporal demand	0.474	0.056	0.663
	Effort	0.194	0.044	0.344
3	(Constant)	8.454	4.499	
	Temporal demand	0.491	0.053	0.686
	Effort	0.235	0.045	0.416
	Performance	0.094	0.038	0.148

related to object size, shape, color, texture) whereas no such mechanism is involved for processing spatial information (i.e., information about the location in space where the object is located) [19]. Postle et al. [20] also reported that the working memory of humans make use of a strategy of verbal coding for processing the object appearance information. This verbal coding mechanism is strong enough to the extent that humans use it for non-verbalizable asymmetrical shapes. The findings of this study indicate that during in-vehicle object distraction the mechanism of verbal coding is negatively affected due to which the drivers experienced more cognitive workload while processing object related information. Since verbal coding is not involved in processing spatial information, the memory for spatial location of the objects is not affected, hence lesser cognitive workload [21].

With respect to the effect of expertise on the cognitive workload of drivers, the results demonstrate a significant difference between novices and experts. Any task that is not performed routinely (or that a person is not habituated with) would require controlled and conscious monitoring from the performer of the task. Same applies to driving a vehicle also. Driving is a task which is performed under dynamic environments and involves a risk of meeting accidents. Since novice drivers don't have enough driving experience and lack exposure of driving environment, they require a substantial proportion of available cognitive resources in order to drive safely. In the case of expert drivers, because of their vast exposure, they have automatized certain subtasks of driving [22] due to which some of the cognitive resources would be left unused, hence they would experience less cognitive workload. There is scientific evidence which indicates that compared to experienced drivers, there is an increase in reaction time for identifying and responding to road hazards in the case of novice drivers [23].

This experiment was performed in a safe driving environment, i.e., test track, where the movement of any other road user was totally controlled. There could be some variation in the experience of cognitive workload by drivers if the same study

was performed in a real traffic environment. Probably they would experience more cognitive workload in a real traffic environment.

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Combined Use of Selected UX Research Techniques and Creation of User Persona for Design and Evaluation of Sustainable e-Commerce Apps—A Case Study

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Abstract The advent of digital economy, the expansion of Internet user base, the surge in the number of smartphone users, and the increasing interconnectedness of man, machines and organizations have fuelled a phenomenal growth in the market penetration of e-commerce worldwide. The disruption of physical shopping by COVID-19 outbreak and the consequent change in consumer behaviour, leaning more towards online shopping, has also significantly pushed up that growth trajectory. The proliferation of e-commerce-apps is a complementary component of this phenomenon, and the competition for sustainability and growth of these apps and the associated companies is ever-increasing. The above developments have necessitated the according of heightened attention to User Experience, i.e., UX, and cognitive response, manifested in consumers' need, preference, attitude, behaviour and comfort, in designing new e-commerce apps and continually improving the existing ones. For meeting this need, a plethora of tools and techniques are available for informing the design process from the perspectives of end-users for enhancing user-centric design efficacy and productivity of the apps. In this paper, a methodology of combining six UX research techniques has been deployed and a user persona has been created in a novel framework by selecting an existing e-commerce App and engaging a consumer newly opting for online shopping. Pain points have been explored and scopes of improving the App identified. This methodology of bettering usability and user experience would be useful for the design and testing of not only e-commerce apps but also of apps developed for numerous other fields of applications.

Keywords UX research · e-commerce app · Online shopping · User persona · Sustainability · Design efficacy

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1 Introduction

The Internet, the World Wide Web and cyber-physical systems have become intertwined with the lives of a majority of the world's population in almost all fields of activities. Since advent, these entities brought in radical alterations in the areas of commerce and consumptions, particularly in the ways consumers compare, choose, and buy products and services, and the ways companies present and deliver their products to consumers [1]. These alterations are being driven by (i) changes in consumer-behaviour due to hectic schedules yielding less time for physical shopping, (ii) growing interconnectedness of man, machines and organizations, (iii) increasing data-speeds, (iv) rising smartphone penetrations, (v) increasing ease of access to information on a vast multitude of products, producers and sellers to explore from the comfort of consumers' homes, etc. All these have fuelled a phenomenal growth in the market penetration of e-commerce worldwide that, besides promoting an escalated use of e-commerce by experienced users, initiating novice consumers to e-commerce by making them shift from physical to online shopping. The onset of pandemic in March 2020 by COVID-19 outbreak has also played a forceful role in this market penetration by restricting consumers from going to brick-and-mortar stores and making stores come to homes instead. It is likely that, even after the pandemic, a large section of consumers would continue using e-commerce worldwide, and consumer-behaviour would further get modified by new regulations, facilitations and means of attaining work-life balance.

The expansion of e-commerce and e-marketplaces call for all businesses to come up with focused actions to either ratify or establish online presence. These actions range from establishing and retaining social bonds to creating, propagating and maintaining websites and web- and mobile-applications or *Apps*. Apps act as a User Interface (UI) for Human–Computer Interaction (HCI) enabling online shoppers to experience, compare, choose and buy products and services from e-marketplaces. For effective, efficient and attractive UI, App-developers require focussing on usability [2, 3], hedonic factors of human needs [4, 5], and web and App-aesthetics [6]. Although App-developers attempt to incorporate UI design elements while working on HCI to create a product, yet, end-users of their products often experience cognitive load [7] to varying degrees. The more usable is the HCI of an e-commerce App, the less cognitive cost the end-user expends and the more effective the App's UI becomes in performing as a decision support system [1] for the end-user. It is therefore important that all Apps undergo usability engineering for identification and correction of usability defects [8].

In order to inform the design process from the end-users' perspectives to enhance informed, contextual and user-centric design efficacy, an overwhelming number of User Experience (UX) research techniques ranging from lab-based usability studies to in-person interviews to unmoderated online assessments are available. Nielsen and Molich [9] grouped these into formal, automatic, empirical and heuristic types, and Rohrer [10] and Babich [11] advocated 20 and seven techniques respectively. A plethora of these techniques, on one hand, makes it difficult to choose a single

technique because of not being adequate, and, on the other, makes the application of a multitude of techniques untenable [10, 11]. Rohrer [10] observed that design teams often use only one or two techniques that they are familiar with.

In the light of the above, it was considered pertinent (i) to interconnectedly deploy a combination of a carefully selected UX research techniques for making the usability testing more user-centric and efficient, and (ii) to create a user persona therefrom by selecting an existing e-commerce App and engaging a consumer newly introduced to online shopping with the objective of informing the design process about the scopes of the App's further improvement. For meeting these two objectives, a case study was undertaken by deploying six appropriate UX research techniques on a selected App and by engaging a test-user. The novelty of the study is the way the selected UX research techniques were adapted and applied in a structured framework with the overall goal of enhancing the productivity of an e-commerce App through UI design applications by focussing on human factors, and by exploring the cognitive processes and studying the responses of a test-user. This methodology would indeed be useful for the design and testing of Apps, not only related to e-commerce but also to other fields of applications.

2 The e-Commerce App and the Test-User

In this study, the mobile version of *Amazon* of the technology company Amazon.com, Inc. was chosen as the App, and a 62-year retired bank manager from Guwahati, India was identified as the test-user, also interchangeably referred hereinafter as the *user*. The user was novice, non-tech-savvy, and dependent on his daughter for online sourcing of information, products, and services. He was curious to explore his newly-bought smartphone, and, on being approached in May 2020 for this research, agreed to participate with eagerness to learn to use his smartphone for online shopping.

This test-user represents a large section of target-users of web- and mobile-Apps who are typically novice, non-tech-savvy and golden-agers, who prioritize safety of home over visiting brick-and-mortar establishments for shopping due to health issues, pandemic, etc., yet eager to learn using their smartphones for seeking information, purchasing products and services, and transacting online in order to meet their needs.

Here, the motivations for engaging only one test-user came from (i) earlier findings [12–14] that the first user identifies one-third of all usability problems, and a sample of five lets one find almost as many problems as would be found by many more participants, and (ii) the objective of only illustrating the methodology rather than expressly identifying the usability problems of the App.

3 Methodology

3.1 Application of UX Research Techniques

To begin with, the purpose of the study was thoroughly explained, and the Amazon e-commerce App was introduced to the user. The user expressed that he intended to buy a foldable mosquito net. Being novice, he was assisted by the researcher as and when the user wanted assistance and reassurance so that he could undertake and complete the tasks till he reached his goal. For brevity, a brief outline of the application of the techniques is provided in this section, and relevant references are included for readers to further explore, if interested. The techniques were interconnectedly applied for collecting data and testing the usability of the selected App for achieving the objectives.

Card sorting: Card sorting technique [15] was employed by asking the user to group certain labels of commodities written on note-slips based on criteria that made sense to him. Noting that Apps' contents are often structured from developer's, rather than, users' perspectives, card sorting was meant to assess the user's comprehension of the App's structure, and identify any gap in its information architecture.

Hierarchical Task Analysis (HTA): The user was then asked to identify his major tasks, and to proceed step by step from one sub-task to the next by breaking down each task according to his objective of using the App to achieve his primary goal of placing an order by understanding and using the features in the App's interface. Thus, an HTA [16] was undertaken. After completion of each task, the user was asked to rank the level of difficulty encountered in executing it on a scale of 1–5, one being the easiest and 5 being the hardest. These data were used to create a User Journey Map.

Think Aloud Protocol (TAP): In applying the TAP [17], the user was asked to continuously verbalise his thought while performing the HTA. His verbal expressions were recorded on consent, actions and thoughts monitored, and observations noted to assess the cognitive load that he endured.

User Journey Mapping (UJM): In order to visually assess the App's usability through a user's perspective and better the user-centricity of its design, UJM [11, 18] was created by representing every touch point between the user and the App in a time-line by using a *five-point scale* ranging from *very easy* to *very difficult* as the user proceeded from one HTA task to the other towards achieving his goal.

Empathy mapping (EM): During undertaking each HTA task, an Empathy Map [18, 19] was created in order to understand the user at a deeper level from what he *says*, *thinks*, *does* and *feels*, to uncover the user's true needs in order to eventually prepare a *user-persona.*

System Usability Scale (SUS): After completion of HTA, the user was presented with a 10-item questionnaire, each with five response options from *Strongly agree* to

Strongly disagree. An SUS [20] score was calculated from these responses in order to assess the App's usability that is stated to be *above-average* for an SUS score of 68 or more, and *below-average* otherwise.

3.2 User Persona Creation

From the application of the above techniques, a *user persona* [21] of an archetypal user was created from the behavioural attributes, goals, skills, background information, etc. of the user, and the environment in which the user operated, that were expected to represent a larger group of target users of the App. This was used to understand the expectations, motivations and concerns of the user, and to identify the App's features that could further improve its user interface and, hence, usability, to meet the needs of the target users by giving satisfying experiences.

3.3 Documentation

The findings during the usability engineering undertaken in this study were documented using texts, charts and tables. In order to illustrate the complexity of the App from the user's perspective, the user's documented actions were indicated in this paper by asterisks (*) wherever he took more time than that would have been normally expected. This was to explore the applicability of the Hick's or Hick-Hyman Law [22] according to which the time taken by the user increases with the increase in the number of possible choices or stimuli. This paper presents (i) the user's information-processing and cognition skills, and the level of ease in navigating through the App's interface, and (ii) the App's features that indicated scopes of improvement. If incorporated, these indicators would make the App more efficient and user-centric, attracting target-users to the App's continual use, and rendering the associated e-commerce more sustainable.

4 Results and Discussions

4.1 Card Sorting*, HTA and TAP*

The outcome of *card sorting* undertaken by the user is exhibited in Fig. 1, a, b, and that of the HTA in Fig. 1c. From *card sorting*, the user expressed his understanding of the concept of grouping of items in the App's interface, and from the HTA, he identified *eight major tasks* for achieving his goal of making an online purchase using an App in his smartphone. Being non-tech-savvy, he continued asking the researcher

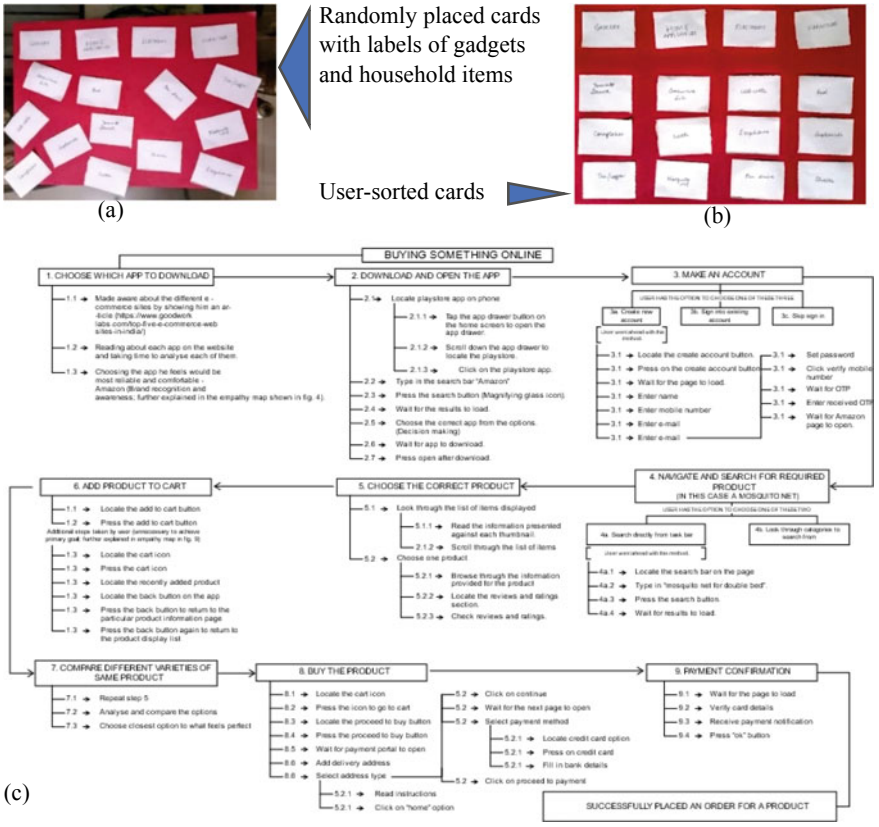

Fig. 1 **a**, **b** Result of card sorting, and **c** user-identified HTA tasks and subtasks

for validation and reassurance to know if he was on the right path as he proceeded. Once validated, he felt happy to have got something right, and moved on.

In the *first* HTA task of *downloading and opening the App*, the user took time to select an App from a list of Apps displayed in the *Play Store* on his smartphone due to a plethora of alternatives, and the mixed reviews and ratings of these alternatives (*). Eventually, he chose the Amazon App by expressing through TAP his belief that this App is likely to be more reliable because he heard many of his acquaintances using and finding this App good for making online purchases. Here the importance of the App's usability in moulding peer-perception, and promoting the App's use came to the fore.

For the *second* HTA task of *making user-account*, the user was confused with the options of signing in to an existing account, making a new one, and skipping sign-in (*). On being clarified, he clicked on the first option by being able to detect and acquire cognitive information from external sources, and by being guided by the thought of not making repetitive efforts for buying a product then and in future. On seeing an *optional* tag for an email ID, the user got curious to know about the

benefit of entering the ID. On being informed that he could recover his password through his email if he ever forgot, and would receive email alerts on the progress of his purchase, he typed in the ID and created his account. From the TAP, it emerged that his decision resulted from his urge to preclude likelihood of future problems, and the ability to track the delivery.

During the *third* HTA task of *navigating and searching for the required product*, the user got overwhelmed by the information displayed on the App's Home page that included categories of items, advertisements of amazon-controlled Apps, links to payment instruments etc. The user looked confused about where to click (*). On being shown a number of alternative features for searching a product, the user chose the option of using the App's *Search bar* as he found it easier to use directly for his product.

While executing the *fourth* HTA task of *choosing the required product*, the user was overwhelmed by the long list of mosquito nets of different types, brands, sizes, sellers etc., and was confused to determine the worthiness of a displayed product (*). On being told to check the ratings and reviews of a product in its display page, he shortlisted the products tagged with *Best seller* by being guided by the thought, as brought by TAP, that this tag would indicate those selling good products. He was still unconvinced due to not being able to physically examine, feel, and compare products (*). The user was reassured that he could return the product even after delivery, if it fell short of his expectations of quality, usability, aesthetics, etc., and choose a different product to buy.

During the *fifth* HTA task of *adding product to the cart*, the user got to know from his query that he could either buy then or add items to an online *Cart* for further review or a later purchase through an analogy with a physical shopping cart. He sensed the meaning of the analogy from the perception of an actual signifier retained in his memory, spotted the *Cart* icon easily, clicked on it, and felt happy as revealed by TAP to have identified something so quickly. However, he was confused by not finding the item in the cart as it opened. On being told to press the *Add to Cart* button on the product page, he did so, and got assured by the visual display of the *Added to Cart* message. He clicked on the cart again for reassurance, and felt happy by finding it there.

In *comparing varieties of the same product* as the *sixth* HTA task, the user examined a number of alternatives saved in the cart, and compared on the basis of ratings and reviews by giving importance to ease of use, durability and price so as to decide (*). He zeroed on a product and felt happy, as revealed by TAP, to have been able to choose a product that appeared closest to his needs and met others' experiences. He was still sceptical about the value for money, but got relieved on being assured that he could get his money back by returning the product if he felt dissatisfied even after receiving it.

During the *seventh* HTA task of *buying the produ*ct, the user pressed the *Proceed to Buy* button without much effort as he was already inside the *Cart*. On filling the details, he selected the address that he entered while creating his account, and pressed the *Deliver to this address* button. He chose the *Credit Card* option of payment,

entered details, and pressed *Continue*. From TAP, these steps appeared fairly easy for him.

For the *eighth HTA* task of *receiving payment confirmation*, the user could authorize the card payment through OTP, and received notifications of the payment confirmation and successful placing of his order. He felt happy and excited to have learnt a new skill, and expressed gratitude for being taught how to shop online using a mobile App.

4.2 UJM in Association with HTA

For understanding the level of difficulty in using the features of the Amazon App by a target-user for online purchase of a product, and hence the App's usability and user-centricity, the responses of the user on the five-point scale as stated in Sect. 3.2 were compiled, and plotted in a graph thereby undertaking a UJM as shown in Fig. 2a.

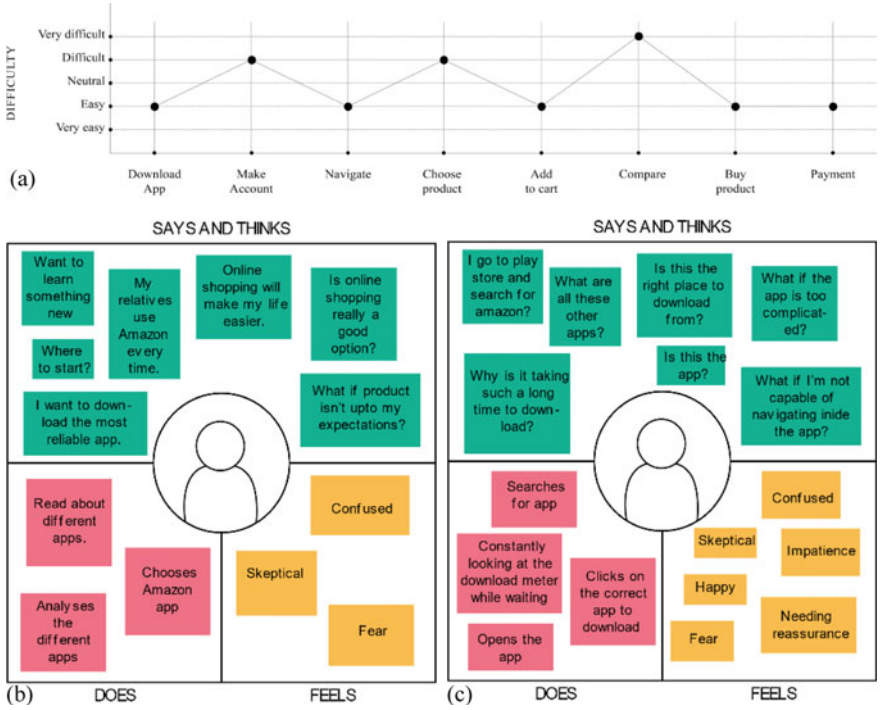

Fig. 2 **a** UJM showing the level of difficulty in executing each HTA task; **b**, **c** EM in **b** choosing an App to download and **c** downloading and opening it for the first HTA task

4.3 EM in Association with HTA

For understanding the user from what he *says*, *thinks*, *does* and *feels*, an EM of each HTA task was created. Hicks' law was found applicable all along while empathising with the user as he proceeded towards achieving his goal. For illustrating the construct of the EMs, and for brevity, only a representative EM associated with the first of the eight tasks of the HTA is exhibited in Fig. 2, b, c, and the tabular entries of the user's responses and the researcher's observations are presented in Fig. 3. The user's expressions of what he *says* and *thinks* and what he *does* and *feels* are entered in Fig. 3a, b respectively, and the *pain-points* of each HTA task are presented in Fig. 3c.

From *pain-points*, the cognitive load on the user could be assessed. It may be seen by correlating the levels of difficulty in executing different HTA tasks in Fig. 2a with the *pain-points* in Fig. 3c that, although the tasks of navigating for the required product and adding it to the Cart were easy, there were still *pain-points* caused by confusions in using the App in performing these tasks; intuitively, the user expressed varying levels of difficulties as reflected in Fig. 2a while making a user-account, choosing a required product, and comparing products. These correlated well with the *pain-points* of the tasks presented in Fig. 3c. The *pain-points* deduced from the UJM and EM provided insight on the prospect of reviewing the App's interface so as to make the App more user-centric and efficient, and outlined the scopes of incorporating modifications, particularly in respect of five HTA tasks as shown in Fig. 3c so that target-users would experience cognitive load less than that endured by the test-user.

4.4 SUS Score

The scores awarded by the user against each of the ten questions of the SUS on completion of the HTA as stated in Sect. 3.1 and the overall results are presented in Fig. 4a. The overall score achieved for the App was 72.5, and the overall ratings of the App's usability as emerged from the SUS were *Acceptable*, *Good* and *Grade C*. Although from the usability engineering undertaken, the Amazon Mobile App was found in this study as being *Acceptable*, the scopes of its improvement as brought out in the UJM and the EMs are also reflected in the SUS ratings that revealed the scope of attaining the ratings of *Best Imaginable* and *Grade A* through the enhancement of the SUS score from 72.5 to 100.

4.5 The User Persona

Finally, from the data collected and analysed during the study, a User Persona was created as shown in Fig. 4b that included his bio-sketch, and enlisted his goals,

(a)

GOALS	Download App	Make Account	Navigate	Choose product	Add to cart	Compare	Buy product	Payment
SAYS & THINKS	I have to go to the play store first? What are all these other apps for? Is this the right place to download from? What if the app is too complex to use?	What happens if I skip sign-in? Why is email optional? What should the password be to make it strong? I might forget the password very easily. Will I be able to recover my account easily if I forget my password? Requests me to remember password as well, in case he forgets.	There are so many categories of products I want to see what products are under this category. Do I need to know what category my desired product belongs to? I think mosquito net will come under home and furniture. Oh, I can search directly as well. I think directly searching for the product will be easier. I'll just type in mosquito net	There are so many options. What if I choose the wrong product? How do I know which one is good? How do I know the product will be long lasting? How do I know if the material is good? Where is the review option? Maybe the best seller would be a good product. In physical shopping, we can compare different products and confirm the products' quality.	I want to save this product to compare with others later while I browse through other options. The add to cart option was at the top of the page, right? If I press the add to cart button, where will I find my cart? The cart icon looks exactly like a physical shopping cart. This icon was relatively easy to notice.	I'll keep browsing through more products to find the best one that I'll buy. I'll keep adding things to cart to compare them at the end. The price is low, but the reviews are bad, so I won't put this in cart. Some of them have similar reviews. What if I don't like the product once its delivered?	I can press proceed to buy now What is the select address type if I have already written down the address? I have to get this delivered to my home address I'll add my credit card as my payment option.	Has the order been placed? I have received payment confirmation notification. What if my product order hasn't been placed but my money has been transferred?

(b)

GOALS	Download App	Make Account	Navigate	Choose product
DOES & FEELS	Constantly asked for validation and reassurance to know whether he was on the right path. Once validated, the user felt happy to get something right. Felt nervous to open the app and start operating as he had a pre-conceived notion that navigating through online shopping must be a difficult and confusing task as he was not that tech savvy.	Read the string of text that appears above sign in options. There was confusion between the options of skip sign in and make a new account. The user was curious to know whether skipping an account would help him complete his goal of buying a product easily or not and wanted to clear that confusion. User made aware that he could carry out the operations written above the sign in options if he made an account. While setting the password, nervously said his memory was not as good before and he might forget. Relieved after being made aware about password recovery through email. Just in case he forgot, as an additional precaution, he timidly trusted me to remember it. On being reassured, he felt grateful for the help.	The user was overwhelmed by the amount of information displayed on the home page The user was skeptical about knowing the category of each and every product that he wanted. Curious about the different products and how they are categorized. Needed reassurance at every step.	The user is overwhelmed by the display of so many options. Skeptical about how he would determine whether the product is worth buying or not. Influenced by the possibility of being popular and hence labelled such, he selects the one labelled 'best seller' to browse first, Giving priority to reassurance and reliability gained from previously experienced user, he directly started searching for the reviews and ratings page. He was still partially in convinced about reliability as in physical shopping, shoppers could physically examine and compare various products.

GOALS	Add to Cart	Compare	Buy product	Payment
DOES & FEELS	The user is happy to have found the *Cart* icon fast because of the perception of an actual signifier retained in his memory (an actual shopping cart). The visual indicator - a message on the screen showing *Added to cart* - after the *Add to cart* is pressed assured the user about the product being successfully added.	The user was very skeptical about the reliability of a product which he couldn't physically check before buying. He felt reassured and told he could return the product with ease and get the money back, though he thought that it would involve additional hassle. The user was also confused between the range of products available. He started prioritizing and filtering out products on the basis of ratings and reviews, giving priority to the ratings of ease of use, durability and price. It took some time to come to a decision. But once he came to the decision, he was happy to have been able to choose one product.	After the user presses the proceed to pay button, the user fills in the required details and comes upon the option of selecting the address type. He gets confused about what to do since he had already put in his address. He presses on the button to explore and reads through the instructions of choosing between home address and office address. Since the options were uncomplicated and less, he did not take time to make the decision of selecting the home address. He selects the payment method as credit card and enters his card details without any difficulty.	The user was nervous about the thought of the money being transferred without the order properly placed. He was assured about the success of order placing on being made aware about tracking of orders. On being asked about his overall experience throughout the process of shopping online, he stated it was easy in terms of being in the comfort of his own space while shopping, though he would still trust physical shopping more with respect to trusting the material, durability and worth.

(c)

GOALS	Download App	Make Account	Navigate	Choose product	Add to Cart	Compare	Buy product	Payment
PAIN POINTS		Even though the string of text displayed before the sign in options highlights the benefits of creating/signing in to a personalized account instead of skipping sign in, this fact is not immediately presented, and it just looks like a display of an unimportant information.	Too much display of information on the homepage, causing cognitive load on the user's mind.	Need to scroll all the way down the product information display page to view reviews and comments. A large volume of information is displayed that can be accessed only through scroll search.	Need to scroll to the top of the page to access the *Add to* Cart feature.	Need to switch between different product information display pages to compare between products of the user's choice.		

Fig. 3 Tabular representation of the test-user's responses as brought out from TAP and UJM in association with EM and HTA—**a** what the user *says* and *thinks*; **b** what the user *does* and *feels*; **c** *Pain-points*

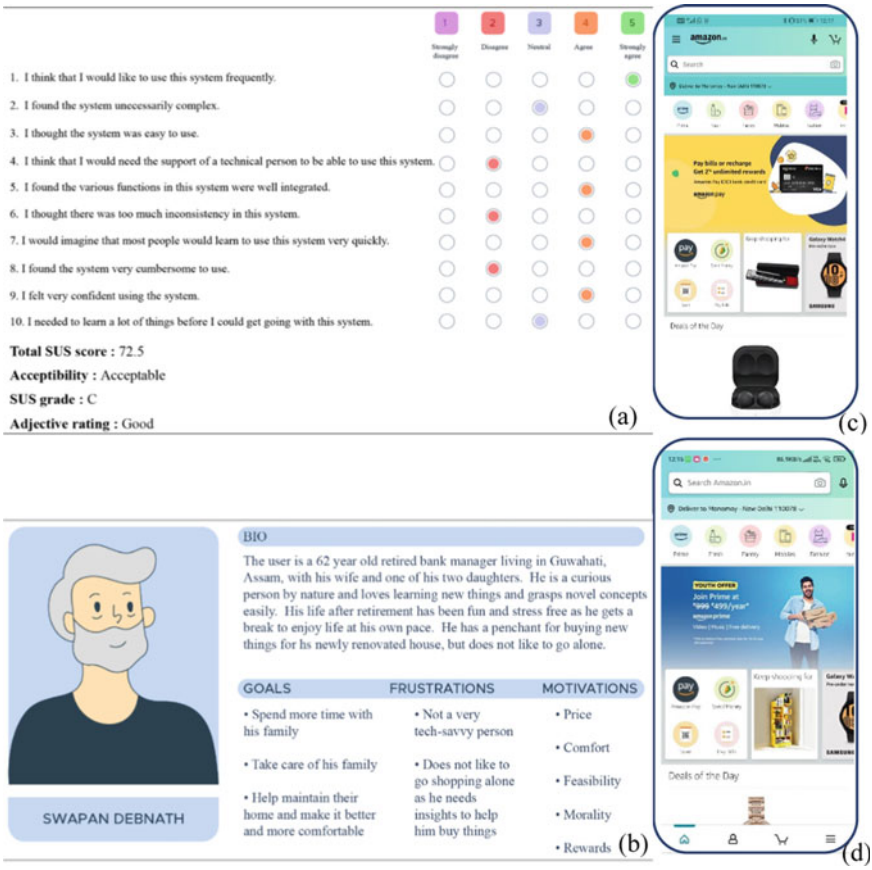

Fig. 4 **a**: SUS results. **b** User persona. **c** Home page of the Amazon Mobile App as of May 2020 and **d** Home page of the Amazon Mobile App as of August 2020

frustrations and motivations. As seen from this figure, the motivations of this user in choosing and buying online products were *price*, *comfort*, *feasibility*, *morality* and *rewards*. This persona represents target-users who would be novice and non-tech-savvy, but eager to use the Amazon App for buying products and services online.

5 Suggestions for Improvement in the App's UI Design

In the light of the usability research described above, the following design interventions to modify the UI design for bettering the UX of the Amazon Mobile App

could be suggested: (i) reorganizing some of the UI design features without overcrowding a display window, e.g., using an easy-to-locate menu-bar or toolbar linking important features from a buyer's perspective, (ii) highlighting the displays and links to the features related to sales more than the contents related to advertisements, EMI options, payment instruments, etc., as the primary use of the App for online shopping would precede the monetizing of the latter features; (iii) creating tabs in the product information display window to facilitate easy navigation to separate sections containing Product specifications, Customer Ratings and Reviews, EMI options, other Sellers, Similar Products, Image Gallery, Offers and Incentives, etc. related to a chosen product; (iv) providing a feature for easy comparison of a selection of products by presenting their respective details as listed at Sl. No. (iv) in a customizable tabular format similar to the features for comparing cars, insurance policies, etc. of e-commerce platforms.

In fact, over the time from May 2020 to August 2021, i.e., between the undertaking of the research and the preparation of the current revision, the Amazon App is found to have undergone modifications wherein some of the above suggestions appear to have been incorporated (Fig. 4c, d). For example, a toolbar linking the homepage, the personal account and the Cart, and providing a Hamburger menu is introduced at the bottom of the revised version that is in line with the suggestion at Sl. No. (i) above.

6 Conclusions and Recommendations

From the usability engineering applied to the Amazon Mobile App by engaging a test-user in this case study, and from the UJM, the EMs and the *User Persona* created by interconnectedly employing a combination of six selected UX research techniques, it emerged that, although the App's features were fairly comprehensible to the user, yet there were *pain-points*. The SUS revealed that the overall ratings of the App were *Acceptable*, *Good* and *Grade C*, and had scopes of being *Best Imaginable* and of *Grade A*. The addressing of the *pain-points* through incorporation of the suggestions for improvement in the App's revised UI design would cause the target-users experience less cognitive load than the test-user by making the Amazon App more user-centric and efficient, and render the App and the associated e-commerce business more sustainable.

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Impact of Work-Related Factors on Musculoskeletal Discomfort Among the Rural Housewives in Central India

Jaita Mondal and Tirthankar Ghosh

Abstract Domestic work has various risk factors and hazards like the other working sector. Studies show women are more likely to MSDs than men as they are consistently found to spend more time at work. The present study aimed to evaluate the prevalence of musculoskeletal discomfort and its associations with work-related factors among the rural housewives in Chhattisgarh, India. The present study was conducted on 500 housewives from selected villages (Kapasda, Raita, Tiwaraiya of Dharsiwa Block, Godhi and Bhansoj of Arang Block) of Raipur district of Chhattisgarh, India. Subjects were selected by random sampling for data collection. Assessment of prevalence of MSDs was done by Standardized Musculoskeletal Discomfort Questionnaire and evaluation of work characteristics by ergonomics checklist. Analysis of body posture by REBA was done to assess the Level of MSD Risk for the postures adopted by the housewives during their daily working activity. Out of 500 housewives, 303 (60.6%) women had musculoskeletal disorders. Out of 303 affected housewives, 39.27% had pain in the hip region, 37.95% were suffering from lower back pain and 19.47% had pain in both the knees. Individual factors such as age, BMI, and the number of pregnancies were found a significant association ($p < 0.05$) with occurrences for musculoskeletal pain in various regions. A Significant association ($p < 0.05$) was found with Musculoskeletal Discomforts and various work-related factors (work type, posture, load, duration, temperature, etc.). This study confirmed the associations of work work-related factors with musculoskeletal discomfort; therefore, a preventive measure at the workplace should be directed to the housewives for the improvement of the work environment, safety awareness, and workload optimization.

Keywords Musculoskeletal discomfort · Work-related factors · Housewives · Lower back pain

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1 Introduction

Domestic work and kitchen work is a task traditionally performed by women [1]. Chopping, stirring, and lifting utensils were found to be complex activities, requiring multiple changes in posture, whereas mopping kitchen platforms and utensil washing was found to be time-consuming tasks [2, 3]. It requires substantial and sustained physical repetitive movements along with sustained work postures which can lead to various musculoskeletal disorders (MSDs) [4–6].

The rural housewives play a major role in managing the family in India. Generally, women are involved in various domestic works but are usually not recognized. They are engaged in verities of domestic tasks both inside and outside of their homes that cause severe hardship and affect their health in some ways. Particularly rural women of our country have to engage in cultivation works in their land and other's farmland, apart from their strenuous domestic chores [7].

Musculoskeletal Disorders are defined as a group of disorders that affect the musculoskeletal system including the nerves, tendons, muscles, and joints, and supporting structures such as intervertebral discs, etc. [8]. Mantyselka et al. [9] founds, musculoskeletal pain continues to be a major cause of morbidity with considerable economic and societal consequences. Tuzun [10] documented, Complaints of musculoskeletal (MS) pain/discomfort are associated with a physical disability, and it affects the health-related quality of life.

Work-Related musculoskeletal disorders (WRMSDs) are one of the serious and most common self-reported problems in many occupational settings [11]. The Occupational Safety and Health Administration (OSHA) defined "WRMSD as an injury or disorder of the muscles, tendons, ligaments, joints, nerves, blood vessels or related soft tissue, including sprain, strain, and inflammation that may be caused or aggravated by work". It does not include injuries resulting from slips, falls, trips, etc. [12].

Studies found that there is a progressive increase in musculoskeletal pain among women and it has correlations with age, body weight, physical workload [13, 14]. OSHA listed some common musculoskeletal disorders which cause pain [12]. Women are found more likely to MSDs than men as they are consistently found to spend more time at work. Treaster and Burr [15] describe, in the general population musculoskeletal disorders (MSDs) are much more common among females than in males. Several previous studies explain women are consistently found to spend more time on household activities than did men, and women were more likely than men to have MSDs that resulted in a disability [16, 17].

The present study aimed to evaluate the prevalence of musculoskeletal discomfort and its associations with work-related factors among rural housewives in Chhattisgarh, India.

2 Methodology

A Cross-Sectional Descriptive Survey design was found to be appropriate for the present study to achieve the objectives. The present study was conducted in selected villages (Kapasda, Raita, Tiwaraiya of Dharsiwa Block, Godhi and Bhansoj of Arang Block) of the Raipur district of Chhattisgarh. In the present study population was housewives who resided in villages of Raipur, Chhattisgarh. Data was collected from 500 housewives of Raipur.

Ethical clearance was obtained from the university ethical committee before data collection. The data was collected from the sample in the year 2017–2019. Individual consent was taken from each participant. Interview, observation, and measurement of physical parameters were used as a data collection technique.

A Standardized Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) was used to assess the prevalence of MSDs, which included questions emphasizing individual details, type of work, musculoskeletal disorder symptoms, history of accidents, etc. to investigate the discomfort of work. In our present study, this questionnaire was applied to evaluate the general physical activity, task variety, work stress, working environment, and workstation design of the housewives [18].

This Rapid Entire Body Assessment (REBA) technique was used here to assess the Level of MSD Risk for the postures adopted by the housewives during their daily working activity. This was carried out with the aid of digital photography [19]. Later on, stick diagrams were drawn from freeze-frame video records and analyze by ErgoFellow 3.0 Ergonomics software developed by FBF Sistemas, Belo Horizonte, Brazil.

SPSS 16 (Statistical Package for Social Sciences) package was used for data analysis and calculate the associations between work-related factors with musculoskeletal discomfort among the rural housewives.

3 Result

Data presented in Table 1 shows that the mean age of housewives who all participated in the study was 39.27 (±12.07) years and the majority was between 22 and 35 years of age group. Also shows that the majority of the women were with mean weight and height of 47.88 (±6.23) Kg and 152 (±5.54) cm respectively with a mean BMI

Table 1 Description of general characteristics

Variables	Mean (SD)
Age (years)	39.27 (±12.07)
Height (cm)	152 (±5.54)
Weight (kg)	47.88 (±6.23)
BMI (kg/m^2)	20.71 (±3.2)

of 20.71 (±3.2) kg/m^2. BMI denotes that the majority (60.6%) had normal weight. Only 7% fall under pre obesity and 32.4% were underweight.

From questioner study, it has been found 92.6% of housewives used to cook themselves, among them 90.71% cook in sitting position. The majority (89%) of them do not use any platform to cook, 11% of them uses some stools/platform but that is not height adjustable.61.6% of shelves were kept in an uncomfortable position out of which 31.79% was too high and 67.2% were too low (Fig. 1). The study found 83.6% of housewives clean toilet and latrine themselves among them 88.99% uses long handle brush to clean toilet and latrine both.

Table 2 shows that 86.2% of housewives mop their homes themselves. 80% of them use wood as cooking fuel, among them, 67.88% go to collect wood self by walking more than 2 km distance with a mean of 1.39 (±0.95) km every 1.79 (±1.16) day per week. 93% of them carry water in a big bucket with a mean of 90.22 (±82.38) L per day (Fig. 2). 57.2% of housewives stand for prolong time; 2.55 (±2.97) hours when they work in the field or do labor work. 73.8% sits for a long time [2.61 (±2.36) hours per day] at the kitchen while cooking or cutting vegetable while cleaning/mopping the house.

After administering the Standardized Cornell Musculoskeletal Discomfort Questionnaire, data was represented that, out of 500 housewives, 303 (60.6%) housewives had musculoskeletal discomfort (Fig. 3).

Fig. 1 Position of kitchen shelves

Table 2 Questionnaire responses regarding daily activities

Variables	Yes		No	
	f	%	f	%
Do you mop floor of house self?	431	86.2	69	13.8
Do you go to collect fuel wood self? <2 km >2 km Mean distance walking per day to collect wood 1.39 km (±0.955) Mean days per week going to collect wood 1.79 days (±1.16)	386 124 262	77.2 32.12 67.88	114	22.8
Do you carry water in big bucket/container? Mean liter of water carrying per day 90.22 L (±82.384)	465	93.0	35	7.0
Do you work in standing position for long? Mean 2.55 (±2.979) hours	286	57.2	214	42.8
Do you work in sitting position for long? Mean 2.61 (±2.358) hours	369	73.8	131	26.2

Fig. 2 Housewife carrying water

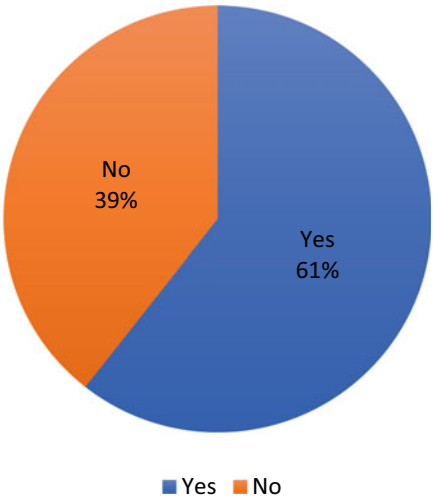

Fig. 3 Prevalence of MSDs among the housewives

Figure 3 shows that out of 500 housewives 61% were suffering from musculoskeletal discomforts and Fig. 4 shows that out of 303 affected housewives 39.27% had pain in the hip region, 37.95% were suffering from a lower backache and 19.47% had pain in both knees.

Association between the prevalence of MSDs with Selected associated factors was assessed by chi-square test at 0.05 level of significance. Table 3 shows that the prevalence of MSDs was significantly associated with self-cleaning toilets ($p = 0.002$) and latrines ($p = 0.005$). Also, with a self-mopping of the floor ($p = 0.007$),

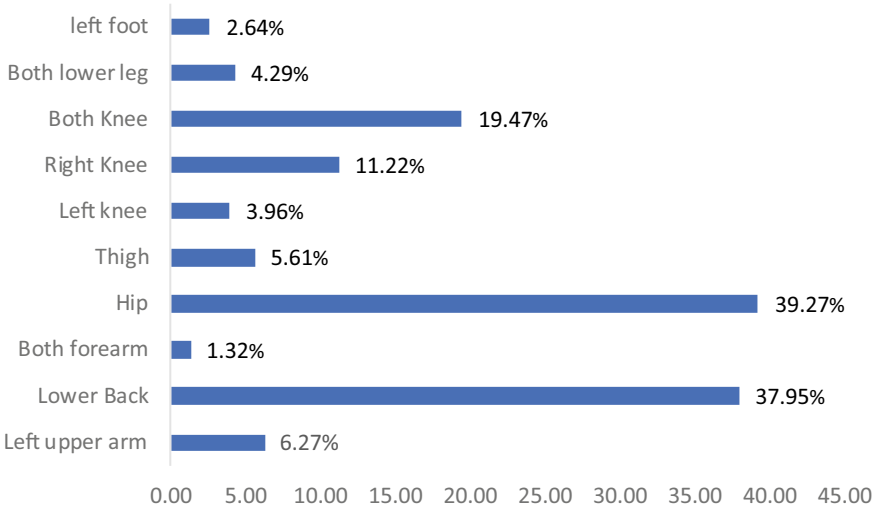

Fig. 4 Prevalence of MSDs in various body parts among housewives

Table 3 Association between prevalence of MSDs with Selected associated factors among housewives

Sl. No.	Sample characteristics	Prevalence of MSDs		df	Chi square value	*p*-value
		Yes	No			
1	Do you clean your toilet yourself? Yes No	241 62	177 20	1	9.255	0.002*
2	Do you clean your latrine yourself? Yes No	238 65	172 25	1	10.643	0.005*
3	Do you mop floor yourself? Yes No	251 52	180 17	1	7.306	0.007*
4	Do you use platform while cooking? Yes No	21 282	34 163	1	13.008	0.0001*
5	Do you reach to your shelves comfortably? Yes No	132 171	60 137	1	8.671	0.003*

*Significant at 0.05 level of significance

use of platform while cooking ($p = 0.0001$), reaching comfort to shelves or shelves height ($p = 0.003$).

Association between various MSDs with Selected associated factors were assessed by chi-square test at 0.05 level of significance. Table 4 shows that lower back pain was significantly associated with self-cleaning of the toilet ($p = 0.0001$), self-cooking ($p = 0.002$), position while cooking (0.0001), self-collection of fuelwoods (0.026), and reachability to kitchen shelves (0.01). Hip pain was also found to be associated with a self-mopping of the floor ($p = 0.024$), self-collection of fuelwoods ($p = 0.011$), self-carrying of water in a big bucket/container ($p = 0.0001$) and work in a standing position for a long (0.001). Knee pain was significantly associated with self-collection of fuelwoods ($p = 0.0001$), self-collection of fuelwood (0.0001), self-carrying of water in big bucket/container ($p = 0.001$), and reachability to kitchen shelves (0.001).

Table 5 shows the Level of MSD Risk for the various postures adopted by housewives during their daily activities by the REBA method. Almost every posture adopted by housewives during their daily activities is having medium or high MSD risk. Among the selected activity, postures adopted for using kitchen shelves, moping the floor, and carry water in the big container are scoring 8–10, which reflects the

Table 4 Association between MSDs in various body parts with selected associated factors among housewives

Sl. No.	Sample characteristics	Lower back pain		df	Chi square value	*p*-value
		Yes	No			
1	Do you clean your toilet yourself? Yes No	73 42	345 40	1	44.105	0.0001*
2	Do you cook yourself? Yes No	99 16	364 21	1	9.246	0.002*
3	Position while cooking No self cooking Sitting standing	16 74 25	21 346 18	2	45.409	0.0001*
4	Do you go to collect fuel wood self? Yes No	80 35	306 79	1	4.946	0.026*
5	Do you reach to your shelves comfortably? Yes No	56 59	136 249	1	6.693	0.01*
Hip pain						
6	Do you mop floor yourself? Yes No	110 09	321 60	1	5.107	0.024*
7	Do you go to collect fuel wood self? Yes No	102 17	284 97	1	6.432	0.011*
8	Do you carry water in big bucket/container? Yes No	101 18	364 17	1	15.841	0.0001*
9	Do you work in standing position for a long? Yes No	85 35	202 179	1	11.434	0.001*
		Knee Pain				
		No	Right	Left	Both	

(continued)

Table 4 (continued)

Sl. No.	Sample characteristics	Lower back pain				df	Chi square value	*p*-value
		Yes		No				
10	Do you go to collect fuel wood self? Yes No	316 79	29 5	11 1	30 29	3	27.73	0.0001*
11	Do you carry water in big bucket/container? Yes No	377 18	32 2	8 4	48 11	3	28.757	0.0001*
12	Do you work in standing position for a long? Yes No	243 152	10 24	7 5	26 33	3	17.896	0.001*
13	Do you reach to your shelves comfortably? Yes No	133 262	24 10	6 6	29 30	3	22.193	0.001*

*Significant at 0.05 level of significance

Table 5 Posture analysis by REBA method for various postures adopted by housewives during their daily activities

‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘‘	Activity	REBA score	Level of MSD risk
	Using kitchen shelves	8–10	High risk, investigate and implement change
	Moping floor	8–10	High risk, investigate and implement change
	Cleaning toilet	4–7	Medium risk, further investigate, change soon
	Carry water in big container	8–10	High risk, investigate and implement change

high level of MSD risk need investigate and implement change to improve the situation. Whereas posture adopted during cleaning toilet score 4–7, which shows the medium level of MSD risk needs further investigation and required change soon.

4 Discussion

The objective of the study was to evaluate the prevalence of musculoskeletal discomfort and its associations with work-related factors among rural housewives in Chhattisgarh, India. The prevalence of musculoskeletal discomfort was found as 60.6% of housewives had musculoskeletal discomfort. In this way, our study results are much higher compared to the estimate of Bihari et al. [20] from North India (31.1%). The present study found, out of 303 affected housewives 39.27% had pain in the hip region, 37.95% were suffering from a lower backache and 19.47% had pain in both knees which follows the common occurrence of work-related MSDs into anatomical areas of the neck, shoulder, and back. Low back pain (LBP) is the commonest MSDs, in which individuals experiencing areas of discomfort due to work-related factors [21].

Several studies were conducted on musculoskeletal discomfort and its association with risk factors among workers in various sectors. These studies had identified pain sensation as one of the highly prevalent self-reported symptoms for MSDs [22]. One of the first major reviews of the physical causes of MSDs, including LBP, was carried out by the National Institute of Occupational Safety and Health (NIOSH [23]). The factors that the review team looked at were a force, leading to muscular stress; repetition, which increases the cumulative loading; awkward postures which put the tissues at a mechanical disadvantage and vibration which causes adverse effects on blood vessels and nerves. The factors where reviewers considered that there was 'evidence of an association were neck pain with repetition and force, force and posture and back pain with heavy physical work and awkward posture [24]

In this present study, in search of impact/association of work-related factors on musculoskeletal discomfort among the rural housewife's chi-square test were done, where it found that the prevalence of MSDs is significantly associated with some risk factors such as self-cleaning of the toilet ($p = 0.002$) and latrine ($p = 0.005$), self-mopping of the floor ($p = 0.007$), use of platform while cooking ($p = 0.0001$), shelves height ($p = 0.003$). These associations resemble the previous findings as ergonomic stressors are positively associated with upper limb disorders/pain and back pain in other workers [25]. As low back pain is the most prevalent MSD among the housewives, in the current study statistical analysis found a significant association between lower back pain with self-cleaning of the toilet ($p = 0.0001$), self-cooking ($p = 0.002$), position while cooking (0.0001), self-collection of fuelwoods (0.026) and reachability to kitchen shelves (0.01). In a study done among rural housewives, it was found that awkward posture, such as bending, lifting, and working in squatting positions, movements of repetition were associated with MSDs in different body areas. The most affected regions were the upper and lower back, wrist, knees, and

elbow [26, 27]. Hip pain was also found to be significantly associated with a self-mopping of the floor ($p = 0.024$), self-collection of fuelwoods ($p = 0.011$), self-carrying of water in a big bucket/container ($p = 0.0001$) and work in a standing position for a long (0.001). Knee pain was significantly associated with self-collection of fuelwoods ($p = 0.0001$), self-collection of fuelwoods (0.0001), self-carrying of water in big bucket/container ($p = 0.001$), and reachability to kitchen shelves (0.001).

From the questioner study, we found 67.88% of housewives are walking more than 2 km distance every 1.79 days per week for finding wood. 93% of them carry water in big buckets with a mean of 90.22 (±82.38) L per day (Fig. 2). Findings indicate a role of substantial risk factors on the prevalence of MSDs and pain at the lower back, hip, and knees among the housewives, who carry loads daily with covering a distance. The association of discomfort and pain exists with exposure to load-carrying, especially for LBP, hip, and other body parts involved in this process. Many epidemiologic studies support the relationships of load-carrying with MSDs and pain [28].

The present study founds majority (89%) of housewives do not use any platform to cook, 11% of them uses some stools/platform but that is not height adjustable. 61.6% of shelves were kept in an uncomfortable position out of which 31.79% were too high and 67.2% were too low (Fig. 1). Poorly designed kitchen is one of the causes of various musculoskeletal hazards, and in lots of houses, women feel that either shelf are very high or very low but just ignores doing it properly. As per a study done by Nag et al. on hand anthropometry in Indian Women, forceful, repetitive usage of kitchen tools, that are not designed as per their hand dimensions and strength ranges, have a higher prevalence of MSDs [29]. Questioner reveals 57.2% of housewives stand for a prolonged time (2.55 h) and 73.8% sit for a long time (2.61 h per day) in the kitchen while cooking. Prolonged standing (regularly) at Kitchen may lead to musculoskeletal discomfort among the housewives. Due to standing positions, the worker may feel discomfort and fatigue, particularly in the lower limb muscles (legs and thighs), lower back, and feet [30, 31].

This association of occurrence of musculoskeletal discomfort with various activities of the housewives can be supported by the posture analysis done by the REBA method. Postures adopted for using kitchen shelves, moping the floor, and carry water in the big container are scoring 8–10, which reflects the high level of MSD risk need investigate and implement change to improve the situation. Whereas posture adopted during cleaning toilet score 4–7, which shows the medium level of MSD risk needs further investigation and required change soon. It is well documented that awkward posture is one of the risk factors for the development of MSDs [32, 33]. The high percentage of unsafe postures is likely a cause of the high frequency of MSDs. This can be attributed to the fact that these tasks are often repetitive and require sustained postures. Repetitiveness has been frequently cited as a risk factor associated with the development of upper and lower-extremity disorders and arise due to overuse of a particular part of the body [34].

5 Conclusion

The study can conclude the prevalence of musculoskeletal pain and discomfort among the rural housewives in central India is. Low back, knee and hip were the most common anatomical locations of pain. Forceful exertion and awkward postures were the important work-related factors, which can be confirmed by the significant associations of work-related factors with musculoskeletal discomfort.

Most of the rural housewives were not aware of work-related risk factors in the household work and irrespective of their pain they are continuing the activities. They are not able to undertake any corrective steps, as they are not considered economically productive or any structural changes in their workstations. Therefore, a preventive measure at the workplace should be directed to the housewives for the improvement of the work environment, safety awareness, and workload optimization.

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Subject Matter Experts Versus OSH Practitioners: Criteria Selection for the Assessment of Pushing and Pulling of Wheeled Equipment in the Workplace

Hari Krishnan Tamil Selvan and Mohd Nasrull Abdol Rahman

Abstract The current study aimed to determine the critical variables for the assessment of pushing and pulling (PP) of wheeled equipment based on the survey conducted among occupational safety and health (OSH) practitioners and subject matter experts (SMEs). An online survey among OSH practitioners and SMEs from the respective industries was undertaken to gain further insight into some of the issues. The online survey selection was based on the mode value as it is more significant compared to the median value for each variable. The variables in the SMEs were chosen based on the validity ratio above 0.59. The number of SMEs provided was 11. Out of the 23 variables in assessing the PP activities, 11 (47.8%) variables (handle height, handgrip, load magnitude, frequency, distance, presence of co-workers, posture, task duration, floor conditions, congestion in the workplace, and the age of workers) turned out to be essential from the OSH practitioners survey. The SMEs' reviews resulted in 13 (56.5%) variables (type of device, wheel diameter, handle height, handgrip, load magnitude, frequency, distance, posture, task duration, floor condition, obstacles along route, congestion and gender). It is interesting to observe that most of the variables were not considered in the currently available risk assessment tool targeting PP. Therefore, it is reasonable to develop a new assessment tool for PP activities by considering the input from the OSH practitioners and SMEs.

Keywords Pushing and pulling · Subject matter experts · OSH practitioner · Ergonomics · Observational-based risk assessment · Wheeled equipment

1 Introduction

Manual handling of material had resulted in a wide range of musculoskeletal injuries [1–5]. PP using wheeled equipment has been introduced in reducing the demand for usage of workers' musculoskeletal system during manually handling tasks [6]. The

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proper adoption of PP measures can reduce the force required compared to other manual handling activities. Nevertheless, it exposed workers to other injuries [7, 8] as complex biomechanics are involved during PP activities [9].

Yang et al. [2] asserted that accident cases were the highest during PP than other manual handling tasks. The Health Council of the Netherlands [10], Hoozeman et al. [11] and Yang et al. [2] had reported that lower back and shoulder injuries were prevalent during the PP activities. One of the critical elements in ergonomics management through assessment is reducing musculoskeletal injuries [12]. The task of occupational risk management and assessment is the OSH practitioners' responsibility in most organisations.

David [13] recommended that ergonomics risk assessment can be divided into three approaches. The approaches suggested are self-report, observations methods (simple and advanced technique) and direct measurement. Observation methods often fulfil the requirements of OSH practitioners due to speed and cost-effectiveness [13]. Currently, the OSH practitioner uses observational-based assessment such as Key Indicator Method-Pushing/Pulling (KIM-PP) [14], Risk Assessment of Pushing and Pulling (RAPP) [10], and the Push and Pull Check (DUTCH) [15]. Nevertheless, the assessment methods have certain limitations. RAPP [10] and KIM-PP [14] tools failed to consider the handle height for the risk assessment.

However, previous studies have highlighted the significant effect of handle height in PP activities that result in a surge of musculoskeletal disorders [9, 11, 16–18], whereas RAPP [10] and DUTCH [15] did not include the task duration as a criterion. Van der Beek et al. [19] had proposed that the criteria should be considered to understand the total exposure rate in the development of musculoskeletal injuries.

It is also vital for an assessment tool to be reliable [20, 21] and valid [22]. Douwes et al. [15] have conducted a reliability test for KIM-PP [14]. No evidence is available on validity tests conducted for KIM-PP [14], RAPP [10] and DUTCH [15] tools. Thus, developing a new observational assessment tool for PP activities is required while evaluating all the critical variables for PP risk factors. During the development stage, a reliability and validity study must be conducted to prove the effectiveness of the assessment tools.

The criteria selection for the current development of an observational-based assessment is dependent on the inputs from the OSH practitioners and SMEs. In most method development, only SMEs were consulted [23–25], whereas input from OSH practitioners was not included. Thus, the present study has attempted to incorporate inputs from both parties towards the development of an assessment tool.

2 Method

2.1 Subject Matter Expert (SME)

The critical variable identification among the SMEs was made through the content validity method [26]. Content validity ratio (CVR) measures the agreement among the SMEs. This method has been widely employed during questionnaire development and validation [26, 27]. Hence, the present study explores the usage of content validation method for the development of assessment tool. The essential factors required during PP were constructed based on the framework proposed by Mack et al. [27] and Jung et al. [28]. Additional variables such as temperature [29], handgrips [30], task duration [30] and positioning accuracy [9] were added to make the factors comprehensive. Thus, a total of 23 variables was evaluated.

Validation Process

The validation process was done as shown in Fig. 1.

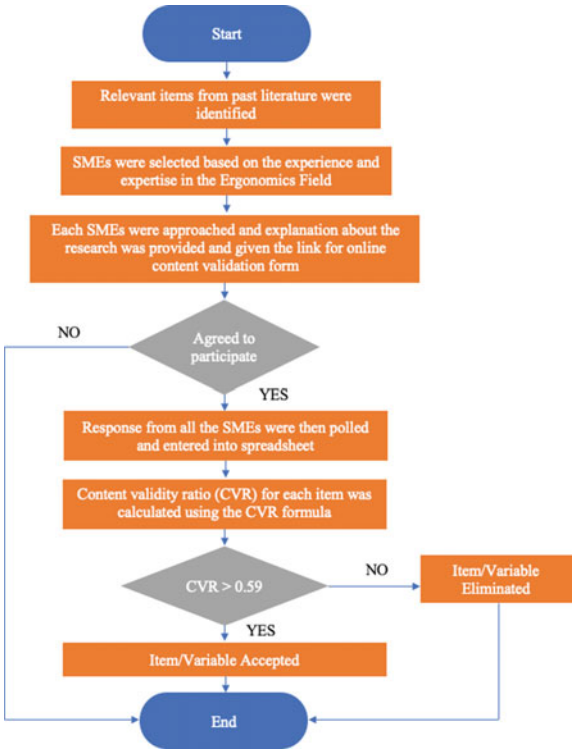

Fig. 1 Validation process

Inclusion Criteria of SME

The inclusion criteria for the SMEs consist of the following:

- An expert with experience of more than five years in the field of ergonomics;
- An expert from Malaysia and globally;
- Made up of two categories: Professional expert and field expert [31]; and
- Professional experts consist of academicians and researchers, whereas field experts are those doing consultation work.

Data Collection

Each SME was contacted on a personal basis. The researchers explained the research objective and the SMEs' roles in the research. Additionally, the SMEs were questioned based on their experience and knowledge. The knowledge is essential to indicate the importance of each 23 variables as the criterion for assessing PP activities. The options provided were "Not Necessary", "Useful but not necessary", and "Essential". The inputs were recorded using an online form.

CVR Calculation

The CVR values for each item were computed using the formula shown in Eq. (1)

$$\mathrm{CVR} = [(\mathrm{E} - (\mathrm{N}/2)/(\mathrm{N}/2))] \tag{1}$$

E The number of panellists indicating the item is essential.
N Total number of panellists.

The value of CVR ranged from zero to one [32, 33]. The estimated CVR value equal to or above the standard value demonstrated that the item was accepted. The value that does not fulfil the criteria will be eliminated. Lynn [30] mentioned for content validity a minimum of 5 panellists would sufficient to provide good level of control for chance agreement. The number of SMEs in this study is 11. The items with CVR less than 0.59 was deleted, whereas more than 0.59 was accepted.

2.2 OSH Practitioners' Survey

The detailed methodology for data collection among the OSH practitioners was reported by other studies [26]. A cross-sectional survey was conducted via the online medium using an instrument consisting of 23 variables and a five-point Likert scale. A skewness test was also conducted to determine the essential variables. The variables were selected if the value of the mode is more than the median value. The detailed results of the survey were reported by Krishnan and Rahman [26].

3 Results

3.1 Demographics Characteristics

Eight SMEs from Malaysia and three from other countries (the United Kingdom, Indonesia and India) provided their valuable feedbacks. Five SMEs are professional expert and field experts. One professional expert is an academician, and five are field experts. The median years of experience for SMEs in the ergonomic field was 16 years. Additionally, 85 OSH practitioners participated in the self-administered online survey. Overall, 54 (63.5%) of them possess more than five years of experience in the OSH field.

3.2 Criteria Selection

Based on SMEs, 13 variables (type of device, wheel diameter, handle height, handgrip, load magnitude, frequency, distance, posture, task duration, floor condition, obstacles along the route, congestion, and gender) were critical inclusion during the PP assessment. On the other hand, the OSH practitioners' survey identified 11 variables (handle height, handgrip, load magnitude, frequency, distance, presence of co-workers, posture, task duration, floor conditions, congestion in the workplace and the age of workers) as essential to be incorporated into the assessment tools.

Overall, both parties simultaneously agreed on nine variables (handle height, handgrip, load magnitude, frequency, distance, posture, task duration, floor conditions and congestion) as vital for PP assessment. Table 1 shows the result obtained from the SMEs and OSH practitioners for the essentiality of variables during PP assessment. Table 2 shows the tabular comparison between the variables included in the present observational method for PP and SME.

4 Discussion

The study results demonstrated slightly different views between the SMEs and OSH practitioners concerning the essential variables required during the PP assessment. Out of 23 listed variables, the SMEs agreed that 56.5% of the variables were critical for inclusion in the assessment. Antithetically, OSH practitioners' feedback showed 47.8% agreement on the variables to be incorporated. There are nine (39.1%) variables that were commonly agreed between both groups: handle height, handgrip, load magnitude, frequency, distance, posture, task duration, floor conditions, and congestion.

The KIM-PP [14] tool considers 11 variables, whereas RAPP [10] takes into account 11 variables. Additionally, the DUTCH [15] tool is limited to five variables.

Table 1 Criteria selection for PP assessment

No	Factors/variables	SME		OSH practitioners		
		CVR value	Decision	Mode	Median	Mode > Median
1	Type of device	0.818	Accepted	4	4	No
2	Wheels diameter	0.636	Accepted	4	4	No
3	Wheels surface material	− 0.091	Eliminated	4	4	No
4	Handle height	1	Accepted	5	4	Yes
5	Hand grip	0.636	Accepted	5	4	Yes
6	Loads magnitude/weight	1	Accepted	5	4	Yes
7	Direction of motion (pushing/pulling)	0.455	Eliminated	4	4	No
8	Motion phases (initial and sustained)	0.091	Eliminated	4	4	No
9	Frequency	0.636	Accepted	5	4	Yes
10	Distance	0.636	Accepted	5	4	Yes
11	Speed	− 0.091	Eliminated	4	4	No
12	Co workers	0.091	Eliminated	5	4	Yes
13	Posture	1	Accepted	5	4	Yes
14	Task durations	0.636	Accepted	5	4	Yes
15	Positioning accuracy	0.455	Eliminated	4	4	No
16	Floor conditions	1	Accepted	5	4	Yes
17	Obstacles along route	0.818	Accepted	4	4	No
18	Congestion	0.636	Accepted	5	4	Yes
19	Maintenance of cart	0.455	Eliminated	4	4	No
20	Ambient temperature	− 0.273	Eliminated	3	4	No
21	Age	− 0.455	Eliminated	5	4	Yes
22	Gender	0.818	Accepted	4	4	No
23	Anthropometry	− 0.273	Eliminated	4	4	No

The variation detected among the inclusion of the variables is due to different methods for selecting variables during the development stages. The usual criterion for the selection method is via comprehensive literature review [10, 14, 15] and inputs from SMEs [10, 14].

It should be noted that the observational-based assessment tool should be user friendly, eliminates the measurement of force, and requires minimal expertise of knowledge to apply (10). These elements are essential to promote risk assessment tools among the OSH practitioners in the mitigation of risk. Thus, the final set of

Table 2 Comparison between PP assessment tools and survey results

Variable category and variable	Assessment tools			Survey results	
	KIM-PP [14]	RAPP [10]	DUTCH [15]	SMEs	OSH Practitioners
Type of device	•	•		•	
Wheel's diameter				•	
Wheels surface material					
Handles height			•	•	•
Handgrip		•		•	•
Loads magnitude	•	•	•	•	•
Direction of motion (pushing/pulling)					
Motion phases (initial and sustained)					
Frequency	•	•	•	•	•
Distance	•	•	•	•	•
Speed	•				
Co-workers					•
Posture	•	•		•	•
Task duration	•			•	•
Floor conditions	•	•		•	•
Obstacles along route	•	•		•	
Congestion				•	•
Maintenance	•	•			
Ambient temperature		•			
Age					•
Gender	•		•	•	
Anthropometry					
Strength					
Others	• a, b	• c			
Coverage of variables	11/23	11/23	5/23	13/23	11/23

Note
a—Positioning accuracy
b—Slope, stairs, and curbs
c—Unstable load; the load is large and obstructs view; the load is sharp, hot and could damage touch; poor lighting conditions; strong air movements; personal protective equipment obstruct the work

variables chosen to be included for assessment should fulfil the usability of the assessment tool.

In accordance with the comparison between the present assessment tools and the result obtained from the survey, it can be concluded that load magnitude, frequency, and distance play a critical role in assessing PP. The variables have been considered in the previous assessment tools [10, 14, 15] and are further supported by the current study. It is evidence that load magnitude can impact spine compression (9,11,31), lateral shear [9, 11], anterior and posterior shear force [9, 34], PP force [11, 35–41], low back movement [11, 34], movement time [42], peak velocity [42], oxygen intake [41] and heart rate [41, 43].

An increase in PP frequency results in the PP decreases for the sufficient force [44–47]. Hoozeman et al. [48] previously recommended that frequency be considered a determinant for the PP risk factors. Additionally, Van Der Beek et al. [19] justified that frequency will lead to a cumulative effect on employees in the development of musculoskeletal injuries. Likewise, the maximum acceptable force reduces when the distance of PP increases [14, 46–49]. Woldstad and Chaffin [42] reported that the distance of PP is associated with velocity and duration.

Due to a mismatch between the feedback provided by the SMEs and OSH practitioners, it is reasonable to incorporate another selection criterion, such as evidence from literature, to verify the critical criterion during the PP assessment. The incorporation ensures the robustness of the assessment tool without omitting any crucial variables and improving the methods' validity.

5 Conclusion

The current study has identified that the SMEs and OSH practitioners commonly agreed on nine variables: handle height, handgrip, load magnitude, frequency, distance, posture, task duration, floor conditions, and congestion. The development of an observational-based assessment tool should consider the majority of the critical variables. The consideration ensures the validity of the tool and high usability score. Thus, the epidemiology evidence from the literature should be considered during the final selection of criterion for observational-based assessment for PP activities.

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Impact of Practicing Bharatnatyam Dancing on Obesity Status in Terms of Adiposity Indices in Human Resources Engaged in White Collar Jobs: A Study in Bengalee Females

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Abstract Occupationally engaged individuals spend a quarter of their lives at workplace and the type of job may influence their dietary habits and physical activity status. In white collar jobs, occupational sitting time of employees is much more compared to other forms and hence there is a high chance of becoming obese. Bharatnatyam dancing (BD), On the other hand, is a popular mode of recreational activity among Bengalee women. An attempt in this context was made to assess the effect of practicing and performing of BD on body adiposity status in Bengalee female human resources occupationally involved in various white collar jobs. Obesity status of 96 Bengalee women occupationally involved in desk jobs and regularly practicing BD has been assessed in terms of several conventional and relatively novel adiposity indices. Results are compared with 87 female individuals of comparable background except engagement with any form of regular physical exercise. It has been found that BD practicing group has significantly ($P < 0.05$) healthy adiposity status in terms of both traditional and novel indices compared to their control group counterparts. As work characteristics of white collar jobs involve no or very less physical works during the working hours, lifestyle modification with enjoyable form of physical exercise is all the more relevant and in this regard workplace can be a target location for promoting healthy behaviors for the human resources.

Keywords Abdominal volume index · Employee engagement · Health promotion programs · Occupational sitting duration · Weight-adjusted-waist index

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1 Introduction

Obesity is identified as both a disease in its own right [1] and a risk factor of a wide range of non-communicable diseases [2]; moreover, recent studies have identified obesity as a risk factor for COVID-19 severity also [3]. Therefore, it is a matter of concern for developing countries like India which is already burdened with other infectious diseases, under-nutrition, micronutrient deficiencies and like problems. Due to increased urbanization, lifestyle pattern, both habitual and occupational, especially in urban areas, has been changed a lot [4]. Occupationally engaged individuals may spend as much as half of their waking hours in the workplace [5] and it has been reported that white collar workers have lower volumes of occupational physical activity [6] with increased occupational sitting duration. On the other hand, Dance is an accessible, widely enjoyed, and appealing creative leisure pursuit [7]. Bharatnatyam dancing (BD), a popular classical and traditional dance form of India, requires various postures of the body and body movements in a rhythmical manner. Hence, in addition to the aesthetic aspects, Bharatnatyam is also physically demanding activity. Previous studies have found significant favorable impact of practicing dance including BD on various physiological variables [8] including pulmonary function [9, 10], cardio-vascular status [11–14], diabetes status [15, 16], psychological health status [17] including motor ability [18, 19] and cognitive ability[20]. There is a dearth of research works that specifically focus on effect of regular practicing of BD on adiposity indicators among white collar workers in Bengalee population. In this context, present work aims to study the effect of regular practicing of BD on adiposity status of Bengalee women occupationally involved in white collar jobs. Various anthropometric indices have been identified as indicators of obesity, and hence in the present work, adiposity status is assessed in terms of both traditional and relatively new adiposity indices.

2 Methodology

96 Bengalee women (25–30 years), engaged in different types of white collar jobs, regularly receiving training in BD and performing it for minimum five years and practicing at least five days in a week with average half an hour period per day either at their residences or in reputed dancing institutions, and 87 individuals of similar background in terms of age, gender, occupation and socioeconomic status with no history of exercise training including any dance form, participated in the present study and respectively constituted the Bharatnatyam Dancing Group (BDG) and Control Group (CG). The exclusion criteria of the present study was individuals receiving BD training for < 5 years, involved in other forms of exercise and also other dance forms, and with any major ailments.

Ethical permission and individual consent: The study was conducted on obtaining necessary ethical permission and receiving consent from the participating volunteeres.

Age (year), occupation, lifestyle pattern and allied information were collected. Updated Kuppuswami socio economic scale [21] was applied to assess the socio economic status of the study volunteeres. BMI was calculated using ratio of measured body weight (kg) (using digital scale to the nearest 0.1 kg) to squared value of stature (m) (using stadiometer to the nearest 0.1 cm), with participants in light indoor clothing and no shoes. The Neck Circumference (NC) [22], Waist Circumference (WC) and Hip Circumference (HC) were measured according to the protocol [23]; Waist circumference to Hip circumference Ratio (WHR) was computed. A Body Shape Index (ABSI), Body Roundness Index (BRI), Abdominal Volume Index (AVI) and weight-adjusted-waist index (WWI) were calculated according to the following formulae [23]:

$$\text{ABSI} = \frac{\text{WC}}{\text{BMI}^{2/3}\text{height}^{1/2}}$$

$$\text{BRI} = 364.2 - 365.5 \times \sqrt{1 - \left(\frac{(\text{WC}/2\pi)^2}{(0.5 \times \text{height})^2}\right)}$$

$$\text{AVI} = \frac{2 \times (\text{waist})^2 + 0.7 \times (\text{waist} - \text{hip})^2}{1000}$$

$$\text{WWI} = \frac{\text{WC}}{\sqrt{\text{weight}}}$$

To reduce the inter-observer measurement error, all anthropometric measurements were taken by one trained researcher, during morning hours.

Analysis: Collected data were tabulated in the spreadsheet. Student t test and ANOVA were performed using Microsoft Excel and SPSS. Direct and derived indices were analyzed to find whether any significant difference exists with significance level fixed at $P < 0.05$.

3 Results

The study participants were Bengalee women engaged in white collar jobs (teaching) (age in year BDG: 26.8 ± 1.92 and CG: 27.1 ± 1.25 [Arithmatic Mean ± Standard Deviation (AM ± SD))] residing in and around Kolkata Metropolitan Area. All of the individuals belonged to upper middle class. Comparisons between CG and BDG individuals in respect of obesity status have been made.

Figure 1 represents the comparison between CG and BDG individuals of obesity status in respect of select traditional adiposity markers.

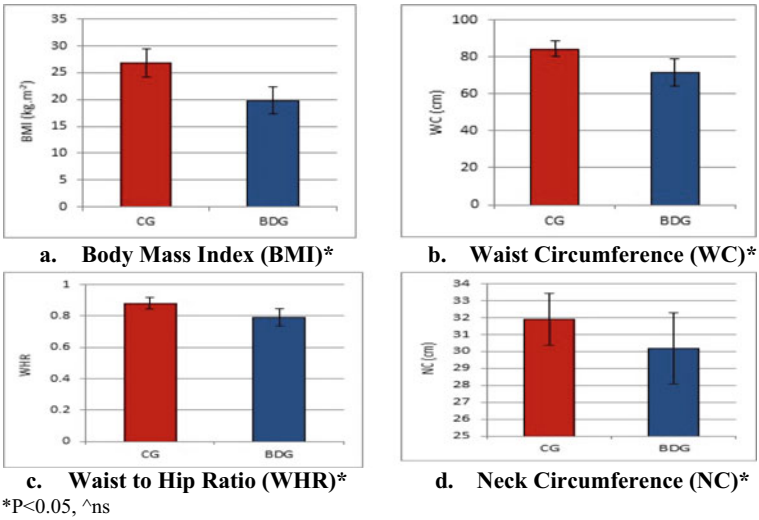

Fig. 1 Comparison between Control Group (CG) and Bharatnatyam Dancing Group (BDG) individuals in respect of select traditional adiposity indices

BDG individuals have been found to have significantly lower ($P < 0.05$) mean values of all traditional adiposity indices compared to CG participants. A significant ($P < 0.05$) negative correlation ($r = -0.91$) has been obtained between the dancing experience (year) and BMI, the most popularly used indicator of obesity status has been obtained and similar trend of significant ($P < 0.05$) correlation has been found for all other traditional traditional adiposity indices.

In Fig. 2, obesity status, in terms of select novel adiposity indices, has been compared between CG and BDG individuals.

Mean values of BRI and AVI, two relatively novel adiposity indices, of BDG individuals have been found to be significantly lower ($P < 0.05$) compared to CG volunteers and significant ($P < 0.05$) negative correlations have been obtained between the dancing experience (year) and BRI and AVI; although no such significant differences have been obtained in case of ABSI and WWI, which have further been corroborated with no such significant correlation between dancing experience (year) and ABSI and WWI.

4 Discussion

As occupationally engaged individuals spend a significant portion of their waking hours at workplace and the nature of work are serious influencing factors of their eating habits and physical activity patterns, maintaining their health and wellbeing are quite challenging. As reported earlier, physical exercise along with balanced

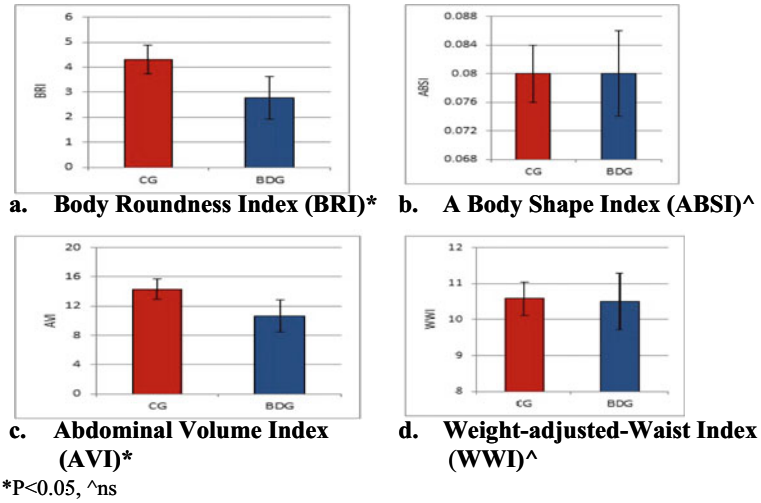

Fig. 2 Comparison between Control Group (CG) and Bharatnatyam Dancing Group (BDG) individuals in respect of select novel adiposity indices

diet is the key for healthy body and mind [24], their implementation is earnestly needed in every sector. Dietary [25, 26] approaches are also there to address the problem. In white collar jobs, occupational sitting time of employees is much more compared to other forms of work and in this regard regular physical exercise is all the more important. Although various forms of structured physical exercise have shown promising results [27–31], all forms are not enjoyed and culturally appropriate for adult women. While on the other hand, BD can be an enjoyable form of physical exercise especially for females; in this backdrop, present work was planned.

BMI although a traditional indicator of obesity status is still popular and is used as early screening marker of health status in most of the population based studies. A significantly lower ($P < 0.05$) BMI has been observed in BDG individuals compared to their non-dancing CG counterparts. Similar results were reported from previous studies [32–34]. Despite worldwide acceptance of BMI as an indicator of generalized obesity status, it suffers from serious limitation regarding inability to capture regional distribution of body fat, which is relatively stronger indicator of health risks. In this context, WC is a most useful parameter. A significantly lower ($P < 0.05$) mean value of WC has been found in BDG individuals compared to CG participants; this finding is in tune with prior findings from our group [35, 36]. WHR is proposed as a way of capturing the distribution of body fat. Like WC, similar trend has been found for WHR alos which is in agreement with an earlier study [37]. Upper-body subcutaneous fat distribution is a known risk factor for different chronic non-communicable diseases and NC is an indicator of this upper-body subcutaneous fat distribution. BDG individuals have been found to have a significantly lower ($P < 0.05$) value of NC compared to CG individuals, which is in consonance with an earlier study [38]. In addition to above mentioned markers of obesity status, several relatively

new adiposity indices have also emerged. BRI, ABSI, AVI and WWI are all novel indices and good predictors of body adiposity. In case of BRI, which gives an idea of the shape of the human body figure (an ellipse or oval) and throws light on body fat percentage especially visceral fat depot, a significantly lower ($P < 0.05$) mean value is found in BDG participants than CG individuals. Similar trend is observed in case of AVI also, which is known to reflect visceral fat content through assessing of the entire abdominal volume; present finding is in consonance with an earlier finding [39, 40]. No such significant difference has been obtained in case of ABSI and WWI. Previous study has reported that ABSI is not a better marker of obesity status compared to other traditional indicators [41]; similar thing is applicable for WWI, a unique adiposity index.

Previous works have also reported a high prevalence of obesity related problems in individuals involved in sedentary occupation [42, 43] and our present study in urban setting is in agreement with those studies. It may be further noted that practicing BD is beneficial in reducing the chance of being obese [44].

There are many different types of exercises but most of them are not culturally appropriate for Bengalee women. The health benefits of exercise can be fully accomplished when it is adjusted according to the participants' lifestyles, their cultural context, traditions and specific needs; if these criteria are fulfilled, then only the exercise mode can be included in their daily activities. In this regard, BD can be a suitable option. It is socially and culturally appropriate for Indian women. Hence, Bharatnatyam dancing can be a target mode while selecting type of exercise. It may be of use for the employers in conceptualizing and structuring a low cost but effective wellness program focused for their employees for better work-related outcome [45].

5 Conclusion

The present work showed the significant ($P < 0.05$) beneficial impact of regular practicing of BD on obesity in terms of both traditional and novel adiposity indices in Bengalee female human resources engaged in various white collar jobs. As work characteristics of white collar jobs involve no or very less physical works during the working hours, lifestyle modification with enjoyable form of physical exercise, such as BD, is of importance. Many of the organizations are focusing on allotting a fixed time of physical exercise during the working hours itself; in this regard BD can be an enjoyable target mode of exercise for promoting healthy behaviors for the human resources engaged there in.

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Ergonomic Risk Assessment of Rubber Tappers Using Ovako Working Posture Analysing System (OWAS)

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Abstract Natural rubber is a vital raw material for modern-day industries. It is commercially produced by extracting the latex of certain tree species that contain significant amounts of rubber and the process is called rubber tapping. In performing this operation, workers have to assume awkward postures, including extending of arms, side bending, twisting, flexion and/or extension of the neck, trunk, and wrists. Typically, workers tap at least 300 trees in a day, consequently subjecting them to these hazardous postures repeatedly. Such a cyclic and monotonous work activity involving numerous ergonomic risk factors exposes rubber tappers to great risks of musculoskeletal disorders (MSDs). This study was conducted among thirty rubber tappers in Kerala, India, to assess their working postures and evaluate their susceptibility to MSDs. Participants were directly observed while they were working, and their work activity was also videotaped with prior consent. The OWAS was used for carrying out a video-based posture analysis of rubber tappers to study the effects of their postures on the musculoskeletal system and the need for remedial measures. It was found that 30% of the participants had postures that would slightly affect their body, whereas 26% of participants had postures that had to be corrected soon in line with higher action categories.

Keywords Ergonomics · Natural rubber · Rubber tapping · OWAS

1 Introduction

Natural rubber, due to its manifold applications and unique characteristics like elasticity, toughness, resilience etc., is an essential raw material in modern-day society [1]. It is extracted from trees that contain rubber in their latex by a process called

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rubber tapping [2]. Rubber tapping is a physically exhaustive and labor-intensive occupation [3]. It entails continuous, cyclic work, usually in the early hours of the day and poses numerous ergonomic risk factors [4]. Tapping is characterized by awkward postures involving varying degrees of flexion and/or extension, lateral bending and twisting especially, in the neck, trunk and wrists [5]. Apart from awkward postures, the tapping operation also exerts mechanical stress in the arms and wrists as tappers strip off thin slices of the bark with jerky, to-and-fro movements of the blade [6]. The tapping levels gradually change and may have to be done near the ground or even at levels higher than that of the shoulder [7]. This is done to provide a period of recovery to previously tapped sections. In order to tap trees at low heights, tappers will have to bend their trunks forward and flex their arms and wrists. Flexion and abduction of upper arms with twisting and side bending of wrists is observed while tapping at heights near or above shoulder level. A rubber tapper usually taps around 300 trees in a day, thereby exposing them to these awkward postures repeatedly [3]. It is therefore evident that rubber tapping is a tedious activity involving fast-paced cyclic work, static muscle loading and frequent deviations from neutral body postures. The hand and wrist motion while tapping involves great extents of flexion and/or extension, non-neutral postures, twisting and physical exertion. These ergonomic risk factors make rubber tappers highly vulnerable to musculoskeletal disorders (MSDs) [5].

Meksawi et al. conducted a questionnaire-based survey among rubber tappers in Southern Thailand to estimate the occurrence of MSDs and ergonomic risk levels [8]. Working postures were directly observed and analysed with video recordings using the Rapid Upper Limb Assessment (RULA) [9]. 52.9% of participants reported pain in the lower back using the Borg scale and an average RULA grand score of 5.25 corresponding to an action level of 3 indicated the need for quick medical examination and work routine changes. Pramchoo et al. conducted another study in Thailand to pinpoint physical ergonomic risk factors in rubber tapping that can lead to Carpal Tunnel Syndrome (CTS) [10]. Like the aforementioned study, here also RULA was used to examine hand and wrist postures to evaluate the associated ergonomic risks. In an effort to address this issue, the team designed and developed an ergonomic tapping knife to enhance wrist posture and mitigate CTS symptoms in rubber tappers [11]. They studied the changes in the severity of CTS Symptoms after the intervention by comparing the symptom severity scores of tappers who used the new knife with those who continued using the traditional knife.

Stankevitz et al. distributed questionnaires to 300 rubber farmers as part of their cross-sectional study to gauge musculoskeletal issues experienced by rubber tappers in Sri Lanka and evaluate factors contributing to MSDs among them [12]. Additionally, the Quick Exposure Check instrument (QEC) was implemented independently among 90 rubber tappers to measure exposure to ergonomic risks. It was found that 66% of them suffered from MSDs in one or more regions of the body over 12 months prior to the study. A study conducted by Doi et al. to assess the prevalence of MSDs among Malaysian rubber tappers using the Nordic Musculoskeletal Questionnaire (NMQ) corroborated the aforementioned results [13]. The results confirmed that the highest prevalence of MSDs was in the lower back (74.4%) among the participants, followed by shoulders (53.5%), neck (48.8%) and wrists/hands (48.8%).

Therefore, it is evident that rubber tappers are highly susceptible to MSDs, with many of them already suffering from such disorders. This can be ascribed to the ergonomically awkward postures demanded by their occupation—recurrent abduction of arms, twisting, flexion and/or extension of the neck, trunk, arms and wrists. The neck, trunk and wrists also undergo side flexion frequently. RULA is one of the most widely used tools for ergonomic analysis of postures in rubber tapping, as can be seen from our literature review, which is mainly used for upper limb assessment [9]. However, as pointed out earlier, rubber tapping demands awkward postures from other body regions as well. Factors like the unevenness of the terrain and different tapping heights entail bending of the legs and trunk, twisting of the neck etc. Hence, a method involving full-body assessment would be more appropriate. The Ovako Working Posture Analysing System (OWAS) [14] seems a viable alternative and has certain advantages. Unlike RULA, OWAS does not consist of an extensive worksheet. While working with RULA, the evaluator would need a pen and paper to record and compile the scores assigned to different body regions. Scores are assigned based on the angle of deviation from the neutral posture. Such angle measurements would require dedicated software (for video-based analysis). On the other hand, OWAS is a simple, concise method consisting of a short table that provides a coding scheme based on the posture of different body parts and the force exertion involved. With frequent use and familiarity, the evaluator can easily memorize the scheme and generate results quickly. Moreover, OWAS does not require any additional materials, as in the case of RULA. Therefore, conducting risk assessment with RULA is a laborious process compared to using OWAS for the same. This study aimed to implement the Ovako Working Posture Analysing System (OWAS) among rubber tappers in Kerala, India, to study work postures involved in the rubber tapping occupation and assess the need for ergonomic interventions or other corrective measures.

2 Materials and Methods

2.1 Study Population

This study was conducted among rubber farmers mainly from the northern district of Kozhikode in Kerala, India. Thirty rubber tappers were included in this study after they were informed of its purpose and the data collection methods involved. Oral consents were obtained from these participants prior to data collection. The criteria for selection of participants were as follows: (a) the worker should be a regular tapper, (b) they should have a minimum experience of one year in rubber tapping and (c) must be at least 18 years old.

2.2 Data Collection

A Standard Nordic Questionnaire custom-made for the rubber farming occupation was developed, based on which the rubber tappers were interviewed in-person to obtain information regarding their work activity and their demographic background. In addition, the questionnaire required participants to rate the level of pain and/or discomfort they experience in different body parts while carrying out the tapping operation. Their work was observed directly and also recorded on video. Working postures were evaluated using the Ovako Working Posture Analysing System (OWAS) by capturing frames from these video recordings.

2.3 Ovako Working Posture Analysing System (OWAS)

OWAS is among the earliest ergonomic assessment tools developed for evaluating working postures. OWAS was developed by work-study engineers in the 1970s in association with Ovako Oy, a private steel company in Finland. They aimed to provide a framework for redesigning working conditions by laying emphasis on the discomfort caused by working postures. It is a simple observational technique that can be implemented by work-study engineers, health officers, safety engineers etc., after they have undergone some training. The system was originally intended to consider job tasks that were repetitive and predictable in nature, in industries where the workstations were static, as in manufacturing facilities.

A concise chart illustrates different postures that can be adopted by the back, arms and legs. It identifies four postures for the back, three postures for the arms and seven postures for the legs, as listed in Table 1. Furthermore, the weight being handled during the work task is also considered and is classified into three categories. OWAS expresses every posture in a four-digit code, in which each of the first three digits corresponds to the posture of the back, arms and legs, respectively. The fourth digit pertains to the load carried during the job task. Therefore, this system generates 252 ($4 \times 3 \times 7 \times 3$) four-digit codes, referred to as OWAS codes, to describe the possible working postures. Hence, due to its simplicity and capacity to give instant results, OWAS can be used even by untrained personnel.

Postures are classified into four action categories based on their ergonomic risks and urgency of interventions required. They are listed below.

Category 1 Postures are normal and do not require any special attention, except in a few cases.

Category 2 Postures have to be considered in the next routine check of working methods and will need corrective actions.

Category 3 Postures need consideration in the near future, corrective actions should be taken as soon as possible.

Category 4 Postures have to be corrected immediately (Fig. 1).

Table 1 Identification of each digit for OWAS codes [4]

Posture			Force (kg)
Trunk	Arm	Leg	
1 = straight	1 = both arms on or below shoulder level	1 = both legs are hanging freely (sitting)	1 for < 10 kg
2 = bent	2 = one arm on or above shoulder level	2 = standing on two straight limbs	2 for 10–20 kg
3 = straight and twisted	3 = both arms above shoulder level	3 = loading on one limb while the other is bent	3 for > 20 kg
4 = bent and twisted		4 = standing on two bent limbs	
		5 = loading on one limb while both limbs are bent	
		6 = loading on one kneeling limb, while the other may or may not be kneeling	
		7 = body is moved by limbs (walking)	

Legs		1			2			3			4			5			6			7		
Force		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Back	Arms																					
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

Fig. 1 Determination of action category from the OWAS code [4]

3 Result and Discussion

3.1 Demographic Details

The characteristics of the subjects for the study have been tabulated in Table 2. Thirty rubber tappers are selected for the study with mean age of 49.33. Rubber tappers are videotaped while they perform their work and completed the questionnaire. From these recordings, frames are captured. These frames are used for measuring angles corresponding to different body parts using simple software 'Angulus'. Some angles are illustrated in Fig. 2.

3.2 Evaluation Using the OWAS

The results of the posture analysis have been tabulated in Table 3. The result shows that the fourth digit is 1 in all cases since the physical force associated with the tapping operation usually does not exceed 10 kgf. 30% of the participants have postural codes

Table 2 Demographic characteristics

Gender	Male	29
	Female	1
Age	< 40	5
	40–50	12
	51–60	7
	> 60	6
Height (cm)	Below 160 cm	8
	160–170	12
	171–180	6
	Above 180	3
Weight (kg)	> 80	3
	70–80	6
	60–69	18
	50–59	3
Workplace	Hill station	26
	Low land	4
No. of working days	7	17
	6	0
	5	2
	4	3
	3	4
	2	1
Years of experience as a rubber plantation worker	40+	2
	30–40	7
	20–29	8
	10–19	6
	Less than 10	4
No. of working hours	> 6	13
	4–6	16
	< 4	1
No. of trees tapped per day	1–100	0
	100–200	4
	200–300	7
	> 300	16
Tapping activity	Single round	30

Fig. 2 Body posture **a** Backs, **b** Arms, **c** Legs

Table 3 Results of posture analysis

Subject No	OWAS code	Action category	Subject No	OWAS code	Action category
1	2131	2	16	1221	1
2	2151	3	17	1231	1
3	1151	2	18	3131	2
4	1111	1	19	1131	1
5	4111	2	20	1221	1
6	2111	2	21	1221	1
7	1231	1	22	3231	1
8	2121	2	23	4141	4
9	2121	2	24	2141	3
10	1221	1	25	1131	1
11	3211	2	26	3141	3
12	2111	2	27	1221	1
13	2141	3	28	1131	1
14	3141	3	29	3321	1
15	2141	3	30	4141	4

that belong to the 2nd action category. They will need corrective actions in the near future. 20% of the participants have postures belonging to action category 3, implying that their postures have a harmful effect on their musculoskeletal system. Corrective measures must be adopted as soon as possible to avoid injury. 6% of the participants

have postures that can severely affect their body and require remedial actions in line with action category 4.

It can be observed that when the first digit and third digit take on values equal to or greater than 3 and 4, respectively, the action category required will be 3 or 4. The Fig. 2 shows that when the trunk is either twisted or bent and twisted, with simultaneous bending of legs, the posture is deemed hazardous and requires remedial actions at the earliest. This posture may be assumed when tapping is done at lower levels (near or below the waist level). The unevenness of the terrain, such as in hillslopes, can also contribute to the bending of legs. These factors can contribute to the need for higher action categories.

This study sheds light on the many drawbacks of OWAS. One of the significant flaws of OWAS is that it completely ignores the postures of the neck and wrists. In rubber tapping, it is these parts that are at great risks of MSDs since they undergo significant flexion and/or extension, lateral flexion and twisting. In addition, unlike contemporary assessment tools, OWAS does not distinguish postures based on the different angles of flexion or extension involved. That is, bending in the trunk, arms and legs are given the same postural code regardless of the angle in which they are bent, thereby ignoring the greater ergonomic risks that can accompany greater flexion angles in different body parts. Moreover, since OWAS evaluates only a limited number of postures, it does not consider many other ergonomically awkward postures that are prevalent among rubber tappers such as side bending of the trunk, abduction and rotation of arms etc. Therefore, it is clear that OWAS cannot be implemented as a suitable tool for evaluating MSD risks associated with the rubber tapping occupation.

The results of the posture analysis have been tabulated in Table 3.

3.3 Comparing OWAS and RULA

It was mentioned in the introduction that Meksawi et al. had applied the RULA method to observe and assess working postures among rubber tappers [6]. For the upper arms, 3.27 was the average score, indicating that on average, the upper arms were raised above the shoulder level. Similarly, for the trunk the average score was 2.77, which could be because the trunk was either in flexion, side bending, twisting or in a combination of these positions. An average score of 1.93 for the legs indicates that uneven balancing of the legs is common.

Based on the RULA grand scores, 32% of participants had postures associated with a low-risk level of MSDs, since their scores were either 3 or 4. For 42.85% of participants, grand scores were either 5 or 6, indicating that they were at medium risk of MSDs and would require changes soon. Finally, 25% of participants had a grand score of 7 and were at high risk of MSDs, requiring immediate changes.

According to the results in Table 3, 33% of participants have a digit greater than 1 as the second digit in their OWAS code, indicating that their postures involve raising their arm(s) above their shoulder. The first digit is greater than 1 for 60% of the participants showing that their trunks were either bending forward, twisting or both.

As for the third digit, 56% of participants have values in the range 3–5, showing that either both legs are bent or that loading is on one leg.

Thus, it can be seen that the results with both methods agree upon the commonly observed postures in rubber tapping. However, according to the OWAS results, the proportion of participants corresponding to higher action categories, thereby higher risks and requiring changes more urgently, are smaller than that obtained through the RULA analysis. It can be because RULA evaluates postures of more body regions, especially those significant for rubber tapping, like the wrists and neck. Furthermore, RULA analyzing the possibility of more awkward postures, such as side bending of the trunk, abduction of arms etc., and generates higher scores if they're present. RULA also considers muscle activity. If the posture is static or repeated more than 4 times in a minute, a score is added. This is especially relevant for work tasks involving cyclic, repetitive work, such as rubber tapping. Therefore, it can be concluded that RULA is a better assessment tool for analyzing postures in rubber tapping and evaluating the associated risks.

4 Conclusion

This study suggests that working postures involved in rubber tapping can potentially lead to musculoskeletal disorders. 30% of the participants had OWAS codes that indicated their postures would have minor effects on their musculoskeletal system (action category 2). 20% of rubber tappers needed remedial actions as soon as possible since their postures were classified under the action category 3. 6% of them had postures belonging to action category 4, indicating an extremely harmful effect and needed corrective measures immediately. These percentages are much smaller than what has been reported by many previous studies. This can be due to the many flaws associated with OWAS that make it unsuitable for ergonomic risk assessment among rubber tappers. Tools specific for this occupation need to be developed to resolve this issue.

The MSDs related to wrists are more prone due to the nature of the work. It is the prolonged and recurrent exposure of wrists to awkward and non-neutral postures that make rubber tappers highly susceptible to MSDs like Carpal Tunnel Syndrome (CTS), a medical condition that results in pain, numbness and tingling in the hands and arms. Some design improvements can be made to develop a more ergonomic tapping tool which reduce the flexion of the wrists.

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Mind's Eye and the Cinematic Lens

An Analysis of Metaphoric Themes and Their Cinematic Adaptation in Kirsten Sheridan's '*Disco Pigs*'

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Abstract Filmmakers often face creative challenges in transforming textual narratives into cinematic language. One such challenge is adaptation from a rich literary medium like a play to a film—a medium that relies less on verbal expositions and more on visual cues. In this regard, cinematographic techniques like Unity, Balance, Contrast, Colour etc. in composition and staging help with the encoding of the narrative and the subtext into the medium along with a metaphoric interpretation of the text. Rudolph Arnheim's seminal work, 'Art and Visual Perception' (1974), laid the foundation for bridging the gap between principles of visual design and gestalt psychology. Taking from Arnheim's work, linguist Mark Johnson, in his 'The Body in the Mind', expanded on the metaphoric implications of embodied image schemata by using everyday experiences. In this paper, we analyze how the principles of visual perception are presented in director Kirsten Sheridan's film '*Disco Pigs*' (2001). Referencing the work of Arnheim on visual perception and Johnson's theories of Conceptual Metaphors and the image schemata, the paper highlights Sheridan's cinematic approach in bringing depth to the story telling by allowing layers of subtext and emotion in the moving frame. The paper will illustrate the Balance Schema, through a visual analysis of the film compositions and the story/theme.

Keywords Gestalt theory · Visual perception · Conceptual metaphor theory · Image schemata · Visual balance · Film

1 Introduction

The medium of cinema is now more than a century old and cinematic techniques used by filmmakers to convey the intricacies of their narrative constantly evolve given technological advancements and trial and error. The camera has long been compared

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to the human eye and the frame of the film to a visual field [1]. The nature of the frame is that of a window which allows the audience a glimpse into the 3-walled world of the story and its characters (the fourth wall being the observer). Given its genesis from photography, which in turn followed the medium of painting, cinema follows many of the same techniques used in the composition of both mediums [2]. Except that there is an illusion of motion and the medium is bound by time.

As a student filmmaker, one is taught the basic techniques of storytelling in each of its constituent components. The medium being fundamentally visual and aural, a lot of research goes into visual analysis of films to understand how the makers have made use of the tools at hand to convey complex ideas [3]. Also the time constraint of the medium forces the maker to be fastidious enough to be able to tell the story effectively. In this, a deep understanding of the human nature, perception and cognition come handy. While cinema has evolved, so has our understanding of human psychology, cognition and visual perception. We have now at hand theories, that explain the most basic of human experiences and offer a way to translate these into practice to effectively communicate to the audience. A visual analysis of films then becomes imperative to help future generations make best use of the knowledge to the desired outcome.

While adaptation from a literary medium to that of a cinematic one has been studied extensively [4], the selected film, i.e. Kirsten Sheridan's film—*Disco Pigs* (2001) is different enough in treatment to stand on its own without having to compare it to the play by Enda Walsh. Stills from this film were used as a specimen in Jenifer Van Sijll's *100 Cinematic Techniques* (2005) to briefly demonstrate the oft followed visual principle of Balance/Imbalance. This principle is apt for the depiction of the conventional story structure—that of equilibrium, disruption and the transition to a new equilibrium. To understand how the visual principles used in cinematography correspond to the theories in place, we looked at the current work in the field of psychology, cognition and visual perception.

The objective of this analysis was to answer the following questions: How is the central balance/imbalance schema visually communicated in the film *Disco Pigs* in terms of its visual elements? How does the change in the balance schemata denote the change in the character arcs of the protagonists? How is change denoted in the schema over the course of the film?

Before we get into the visual/textual analysis of the film, a brief overview of the primary theories tapped in this paper is necessary.

1.1 Semantics and Binary Oppositions

While analyzing structures of texts in English language, semiotician Roman Jacobson, a major figure in Russian Formalism, proposed that linguistic units are bound together by binary oppositions which in turn are essential to the generation of meaning, for example the meaning of 'dark' is relative to the meaning of 'light' [5]. The terms that we are the most familiar with within our culture are better termed as

'paired contrasts' and the evocation of which often involves polar opposites. Jakobson further declared that if one of the terms is given, the other, even though not present is evoked in thought. 'opposites are so intimately interconnected that the appearance of one of them inevitable elicits the other'. Jakobson and Halle also observe that a child's first logical operation is that of binary opposition. While such distinct opposites don't occur in nature, as a culture we still use them to help make sense of the dynamic complexity of experience. To understand the theme at work in the selected text, the primary analytical method (preferred by structuralist semioticians) is to identify the binary polar oppositions at work. This involves a study of the narrative, the characters and the overarching theme. Noel Carroll, in her study of Buster Keaton's films, makes the distinction between two thematic levels of organization in film i.e. the 'dramatic' level of organization which is considered the standard operating procedure by only accessing the literary text and the iconographic or imagery level which involves the viewing of the film [6]. Themes can be determined by focusing on a dramatic conflict in the story and then generalizing into a schema of opposing values or forces. The iconographic or imagistic approach considers the visual content of the images and tries to locate the themes of the film through an analysis of its imagery, the arrangement of its visual elements and the use of filmic devices. Maarten Coëgnarts and Peter Kravajna, while analysing the embodiment of binary oppositions in John Ford's westerns take an iconographic approach to demonstrate the CONTAINMENT schema. In their paper they point out that many studies have demonstrated the opposing values are commonly communicated by way of Spatial Schemas or Orientational Metaphors [7].

1.2 Conceptual Metaphor Theory (CMT) and the Balance Schemata

In their seminal work, *Metaphors We Live By* (1980), George Lakoff and Mark Johnson define the metaphor as not simply an ornamental device in language but a conceptual tool for structuring, restructuring and even creating reality. While analyzing how metaphors work in the English language, the linguists found that metaphors are pervasive in everyday life; not just in language but also in thought and action. Metaphorical concepts structure what we perceive, how we get around the world and how we relate to other people. They surmise that the essence of metaphor is understanding and experiencing one kind of thing in terms of another i.e. there is

a Source Domain (S) and a Target Domain (T). Conceptual metaphors are categorized into three types—Orientational[1] (and spatial), Ontological[2] and Structural.[3] It is possible to see that metaphors embody the physical experience which is then used to explain the target domain's own experience. In the book *Body in the Mind*, (1987) Mark Johnson primarily expands on the theories in his and Lakoff's earlier work and writes of rich images (which are rich in detail) and image schemata or image schematic structures which are a far more abstract form, stripped of concrete detail. He defines an image schema as "a recurring, dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience" [8].

Schemata are general knowledge structures, which can be anything from conceptual networks, scripted activities, narrative structures to theoretical frameworks.

Cognitive science studies show that humans often access these ordered units of knowledge-based on past experiences, to direct current understanding or action. Cognitive schemata are dynamic, in that they develop and change based on new information and experiences. They guide interpretation of new information and are powerful in their influence. Schemata allow writers or speakers to make assumptions about what the reader or listener already knows. According to F. C. Bartlett (1932), past experiences help make sense of new experiences by supplying expectations and frameworks for action. Our most basic encounter with objects, for example the perception of a chair, rely on schemata to help different kinds of things or events as different.

The Balance Schema is pervasive and the most basic for our coherent experience of the world we inhabit. It is one of the first activities we learn as humans, the act of balancing our bodies to move about in space. The loss of this equilibrium is also one of the most chaotic occurrences that one can go through, for example, a fall which tilts our world view and possibly causes bodily harm. This disorientation is also one of the most unsettling things about loss of balance, that is to see the world in a view different from normal. Systemic imbalance is also experienced when there is too much or too little of something affecting our bodies, too little water that causes dehydration, too much acid in the stomach, temperature being too hot or too cold. As humans we respond to such imbalances by taking actions to correct it and come to a normal state. This urge to correct the balance is at times completely unconscious and urgent. Our bodies are built on a vertical axis and have to constantly fight gravity which translates to objects around us that are subject to the same laws of gravity, therefore translating the perception of balance from the body to the visual

[1] HAPPY IS UP and SAD IS DOWN are examples of orientational metaphors which have a physical basis and arise from the fact that we have bodies and we experience the world in a certain way. Spatial metaphors also have a basis for 'in' 'out' in physical and cultural experience.

[2] Ontological metaphors are entity and substance metaphors-bounded by a surface, for example, MIND IS A MACHINE and LIFE IS A CONTAINER show how the experience of a mind is elaborated in our culture.

[3] Structural Metaphors are TIME IS MONEY, LIFE IS A GAMBLING GAME and IDEAS ARE FASHION derived by comparing the attributes of the target and the source domains.

medium. For example, a high-rise building can be designed to seem like it is on the precipice of toppling over, or a pyramid structure made to look like an impossible architecture. Rudolph Arnheim, in his book *Art and Visual Perception* (1974) puts forth the idea of balance in paintings with many empirical examples. The act of balancing also gives rise to an imaginary structure that is followed to bring forth balance. Through basic visual examples, Arnheim shows that a hidden structure of tensions and forces prevails in all visual perceptions. A black disk placed in the center of a white background will seem to be either moving in some direction or held still by equal forces from the sides of the form surrounding it. Moving the disk around in the white space, causes the viewer to perceive some relation to the background, and an urge to return the object to the center or to a place which achieves a balance [9]. According to Johnson, if we want to make sense of our experience of the world around us, there needs to be a repeatable pattern or structure to our experiences. 'Image schemata are those recurring structures of or in our perceptual interactions, bodily experiences and cognitive operations'. Therefore, the same parts or relations occur when a number of different experiences or images are instantiated by the same schema. In language for example, the metaphoric implication of balance can be found in ideas that are often used to structure a rational argument. One sets out to convince others of their viewpoint by piling up evidence, amassing facts and building up a weighty argument. The scale of the two arguments may tip by adding further evidence. If we are successful, we tip the balance in our favor. Arnheim gives a brief list of factors that influence the force and weight of any work of visual art to determine balance, namely, location in the plane, spatial depth, size, intrinsic interest, isolation, shape, knowledge and colour. None of these factors exist in isolation of course, and this is a setup for complex interactions. The balance schema involves symmetrical or proportional forces in a dynamic relationship around a point or an axis. This paper will attempt to demonstrate how the balance schema comes into play in the selected text *Disco Pigs*. Besides the use of balance schemata, another important tool for the analysis of film texts is the concept of the containment schema.

The Containment Schema is a simple instance of image schematic structure that emerges from our experience of physical containment. The most basic experience of containment comes from our own physical bodies. This 3-dimensional container has an inside and an outside, things come out from and go into the body. Our surroundings are our next experience of containment, where spaces are demarcated into rooms, buildings, vehicles etc. where we physically enter and exit. In and out orientation can be experienced through spatial boundedness, involving separation, differentiation and enclosure and implies restriction and limitation. Protection, resistance to external forces, relative fixity of location, accessibility or inaccessibility and transitivity of containment are five most common entailments or consequences of the recurring experiential image-schematic structures for in–out orientation. Kravajna and Coëgnarts analyse a scene from the film *Spartacus* (1960), where Caesar is shown to move from the neutral centre of the frame to the left as the conversation about taking sides goes on between three characters. The frame is the container and the men occupy positions in it that are meant to signify the two viewpoints plus a

neutral centres. The movement is inferred as Caesar taking the side of the character that was on the left, as a counter to the argument of the character that was on the right [10]. This is one of the ways in which the containment schema can be used in a cinematic narrative.

1.3 Nature of the Medium and the Audience

The medium of film is time bound, in the sense that the story has to be told in the span of 90–120 min (for feature films). Given the short duration, the film maker has to compress an immense amount of information into the narrative. This includes existing information about the world of the film as well as the change that is brought about by the journey of the characters through the duration of the story. The ultimate objective of story-telling is conveying this very change through the medium of exposition via dialogue and imagery. The medium of film is thus, at its core—fundamentally visual and a popular dictum amongst filmmakers is 'Show, don't tell'. As human beings, we are wired to look for visual cues to help make decisions about behavior/action/reaction while dealing with others of our kind. Subtle cues about body language, other people's actions, change in the patterns of behavior help us navigate through the huge amount of information that we are exposed to on a daily basis. Psychologist Carl Plantinga evokes the Mirror Neuron theory which posits that the "brain processes involving mirror neurons enable us to understand faces and bodies in action and link us to other people's activities and feelings, in turn allowing us to understand and respond affectively to human events and behavior, whether on the screen or in the extra filmic world" [11]. The discovery of mirror neurons also lead to the formulation of the Embodied Simulation Theory which states that the observation of an action activates the same neural mechanism that is triggered by executing that action by the observer. In the intra filmic world, this enables the audience to relate to and experience the emotions of the characters on screen [12]. For human beings, the act of visual perception is one of immediate comprehension. All objects are perceived as having a certain size, location relation to other elements in the visual field. This knowledge comes about by assigning the object (almost immediately) a place in the whole; a spatial location, a unit of size, brightness and distance. According to Arnheim, the visual qualities of images produced by the sense of sight are not static. The object's relation to the edges of the visual field are a play of attraction and repulsion.

1.4 Cinematic Techniques and Filmic Devices

A filmmaker must choose from a wide range of cinematic techniques available to them to be able to communicate a richer narrative. While nomenclature vary slightly, the basic elements used during production remain the same—the camera, its own

point of view (called framing), its movement, lens magnification, the objects within the frame (placement of which is called mis-en-scène)—which include the actors' placements, their movement within the frame, props, lighting and colour. In post-production, editing, vfx and sound complete the broad categories. Not every film has a documented 'making-of' which is available to the public, especially the films made on the analogue platform. But given that the crew members are experienced in the form, we can make certain assumptions about their choice of cinematic devices.

The Rule of thirds is the oldest known convention that is followed across mediums to create visually harmonious compositions. It has come about after hundreds of years of experimentation and development in artistic mediums and is followed quite rigorously in cinematography. Division of the frame by thirds along its width and height gives rise to sweet spots, which can be used as guides to place important compositional elements. Placing the character's eyes on the top left or the top right spot gives the character 'looking room'—which is a 'convention designed to balance the composition by countering the compositional weight of a subjects gaze'[3]. If the character is placed in the middle of the frame, the placement reduces visual tension and makes the composition static. This can also be found in compositions that are symmetrical or balanced. There is no movement in any particular direction, and one could say that the subject is at rest. Cinematographers will use either convention for the desired outcome. The looking room also leads to 'walking room' or space for action. It can indicate the direction of other characters, direction of future movement or conflict depending on context.

Another famous convention is the Hitchcock's Rule. Director Alfred Hitchcock, in his dialogue with Francis Truffaut shared the following simple but effective rule—the size of an object in a frame should be directly related to its importance in the film. While he used this rule to create suspense, it is also very effective in communicating the characters' power dynamics to the audience. CMT has interesting parallels to this phenomenon. In the type—Orientational Metaphors, physical size correlates to physical strength. For example: She is in a *superior* position; He is *under* my control. The victor in a fight is typically on top. The larger a person looks, the more strength he/she has. As children, we view the world bigger than us, when we are at an age where the most common experience is that of weakness or helplessness. This size variation is used in conventional story-telling, especially when the antagonist is introduced with the protagonist in the frame and when the hero finally defeats the villain.

The Weighted Frame is the rectangular frame of the screen which is by no means neutral when it comes to hierarchy. The choice of where to place what and at what angle and magnification and moving in which direction can convey a multitude of meanings. The following devices that are very commonly followed in cinematic framing are derived from reading conventions of most languages that follow the left to right, top to bottom direction; making ascent on the y-axis (Fig. 1a), movement from right to left on x-axis (Fig. 1a), and from bottom right corner to top left corner (Fig. 1c) difficult for the viewer [13]. These levels of ease or difficulty have always

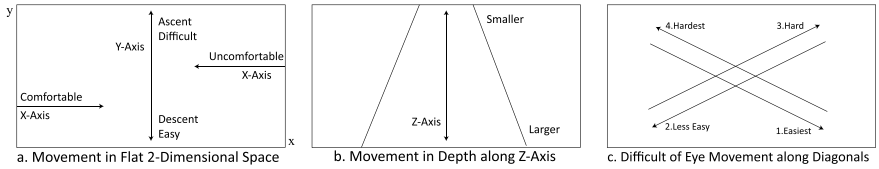

Fig. 1 Jennifer Van Sijll's cinematic screen directions, *cinematic storytelling* (2005), pp. 3–8

been used in filmmaking to convey more information than the dialogue would be able to.

2 *Disco Pigs* (2001)

Disco Pigs, originally written by Enda Walsh as a stage play in 1996, was adapted into a film in 2001 by first-time director Kirsten Sheridan. The play, when it debuted was called a provocative game changer and catapulted Irish theatre to what it is today [14]. Enda Walsh, the author, invented the language for the protagonists, a mix of baby talk and Irish slang, that remains at the core of its treatment on stage. According to reviews, the play for its time was explosive and went on to win many awards, while gaining recognition for everyone involved. With a cast of two actors, the play also employed minimalist sets. In comparison, the film was different from the stage treatment. Reviews called it a hyperkinetic drama about a destructive friendship between the lead characters [15]. Enda Walsh adapted the play for the big screen and changed the treatment to suit the medium. The sets were scaled up and the story received a distinctive 3-act structure. Igor Jadue-Lillo, the principal photographer, used colour, composition, lighting and minimal camera movement to bring about the change in the characters relationship as the story progressed. While the play was highly successful and ran for many years, the film, with its altered treatment, did not do as well with the audiences. Nevertheless, it remains a critic favourite and deserves a closer scrutiny.

2.1 Narrative Structure

Disco Pigs is about a teenage boy—Darren (Pig) and a girl—Sinead (Runt) who are born on the same day in the same hospital and grow up together as next door neighbors. They live in their own world, calling each other Pig and Runt, rarely interacting with the others, and only doing so to show their hostility towards their parents, teachers and classmates. Their relationship borders on dysfunctional and the partners in crime have an appetite for recklessness and destruction. While intense, their relationship is still platonic, and romantic love a thing of shallow fantasy for

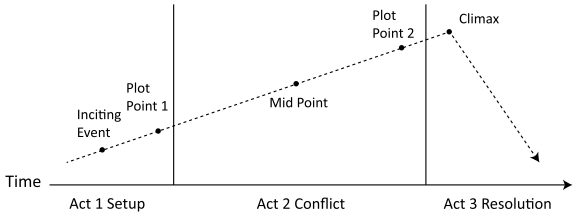

Fig. 2 Syd Field's 3 act structure

both. On the cusp of their 17th birthdays, the characters undergo a sexual awakening that leads them to fixate upon different objects of desire—Pig wanting to initiate a physical relationship with Runt, and Runt taking interest in Mackey, a classmate from school. This is the pivotal moment when conflict arises and the balance between the two shifts. Pig's increasing jealousy and unpredictable nature make for a fast-spiraling end, where Runt, while at first following Pig in his antics, takes a stand and breaks free of their bond.

To analyse the film at the dramatic level, Syd Field's narrative paradigm was used [16]. This is a simple 3 act structure that most stories for the medium can be plotted on, where Act 1 is considered as an existing equilibrium or *setup*, Act 2 as disruption or *conflict* and Act 3 as coming to a new equilibrium or *resolution* (Fig. 2).

Act 1: The first act of the film is all about the two characters, wrapped up in each other, with their own short hand language that leaves the rest of the world entirely clueless. This can be seen in their minimal interactions with their peers, who fail to understand the two, leaving them bewildered and resigned to the odd duo. Their relationship has a bit of chasteness, where physical love is only to be laughed at and made jokes about. Their pranks on others are cruel, with a violent turn on Pig's end. We meet the protagonists, follow their exploits, come to the church tower where Pig sees Runt for the first time in a dress and he is sexually attracted to her. This can be considered the **Inciting Event**. We can distinctly see him change after this, become jealous and unable to express his feelings to Runt. In the meantime, Mackey catches Runt's eye. **Plot Point 1** is when Pig beats up another guy in the disco and kisses Runt without her permission. This is where everything changes and we enter Act 2.

Act 2: Begins with Runt leaving to go away to boarding school and Pig finding out that he's alone for the first time. He is unable to cope and finally his mother agrees to tells him where Runt is if he would leave and never come back. Thus starts his journey to find Runt. At the same time, Runt is on her own journey of discovery where she meets another girl at the school and kindles a tentative friendship with her. Pig eventually finds Runt on the day of their 17th birthday and the two leave the school to go back to Cork to celebrate the day. This is **Plot Point 2**, where Runt decides that she needs to do this for the sake of their bond. It is evident that this day off is temporary because she leaves the album with her new friend, almost like a promise to return.

Act 3: starts with the two characters back in their hometown, and Pigs actions get more violent and desperate, as he sees the possibility that he will lose Runt. The

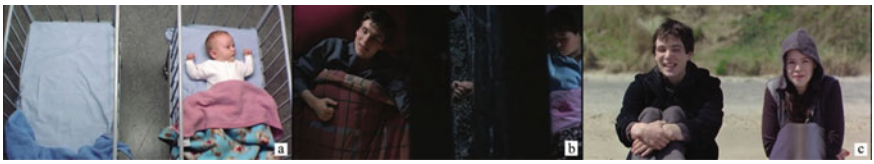

Fig. 3 *Established normal or Symmetry*, screenshots from the film *Disco Pigs*

climactic point comes when Pig kills Mackey in the disco for dancing with Runt. From this point on, the action descends, the deed is done and both characters realise that their child's play has come to an end.

The writer/director sets us up for a balancing act which is at the very core of the story. Pig and Runt are two different individuals who consider themselves a part of an inseparable whole. When conflict arises this balance or equilibrium gets disrupted and sets forth the characters on their individual journeys to find a new equilibrium.

2.2 Visual Analysis of Disco Pigs

The film comprises of 45 scenes that were analysed and all sequences are marked with the following categories with their metaphorical connotations:

Symmetry/Balance is Comfortable: As an established norm[4], when Pig is on the left looking right and Runt is on the Right looking Left, and in the same frame[5] we have a normal situation of comfort for both characters. This begins at the very first scene where we see the characters as babies (Fig. 3a) and continues into the next scene where we see them as teenagers at the beginning of a montage sequence that is their nighttime ritual (Fig. 3b) and a day at the beach (Fig. 3c), established to show us that the two characters are deeply synchronized and almost telepathic in their thought processes. The placement of Pig (left) and Runt (right) is repeated in every 'normal' sequence.

Empty/Absence of the Other is Imbalance: When one or the other characters are composed in their normal frame, but alone, in scenes of discomfort, there is an *absence* of the other. At the start of the conflict we see one or the other character missing from the frame. In these sequences Pig is physically left alone in compositions that we have seen him together with Runt before. Similarly Runt is framed alone without Pig to balance her. For e.g.: Right after Pig forcibly kisses Runt (Fig. 4a), waiting for her to join him on the (Fig. 4b), Runt having an anxiety attack (Fig. 4c).

[4] Established in Act 1, meaning shown to us as a normal, or an equilibrium that we begin with.

[5] Instances of same placement but in different shots have shown to be sequences of discomfort for one or the other character.

Fig. 4 *Absence*, screenshots from *Disco Pigs*

Fig. 5 Switch, screenshots from the film *Disco Pigs*

Fig. 6 Replace, screenshots from the film *Disco Pigs*

Switching Places is Imbalance: When one or the other character or both together are composed as having switched places, there is an imbalance in their relationship. There is also a shift of power and a sense of right and wrong. The first time we see the *switch* in operation is in a flashback where we see Runt's parents fight a lot and the children bear the brunt of the strife (Fig. 5a). At the end of the conflict we see the two back in their positions of comfort. This comfort/discomfort motif is used in pivotal sequences in the film, for e.g. The first time Pig notices Runt as the object of his desire (Fig. 5b), the next time he's in bed after his sexual awakening, Pig's monologue the morning after, Runt having decided to go away to boarding school, the next time they meet at the boarding school, their second scene at the liquor store where Pig has a violent outburst (Fig. 5c), and finally during the taxi ride to the beach.

Replaced Character is Imbalance: When One of the characters is *replaced* by another significant character an imbalance is created as an opposition to the balance of Act 1. If this happens in Act 3, the characters are striving for a new equilibrium. After Pig's feelings for Runt start to change, a classroom sequence (in which, another boy,—Mackey, catches Runt's eye) showcases an interesting triad and a replacement of Pig on the left of the screen. At the end of this sequence we are left with Mackey on the left, Runt on her usual right and Pig framed uncomfortably between them (Fig. 6a) After Runt goes away to boarding school, she tentatively makes friends with her roommate and starts to explore outside her comfort zone (Fig. 6b). At the

same time, Pig on his journey, befriends an old man, and acts possessively towards him, stabbing another man who behaves rudely. In the build up towards the end, we see, Pig replaced yet again with Mackey, leading to a bloody climax (Fig. 6c).

Centred Character is Balance: When either of the main characters are composed in the centre, they are acting alone and of their own volition, without the support of the other. Centre is POWER.

In Act 1, we see more of the *Established Normal* type of balanced compositions with at the inciting incidence, we see the *Switch* in positions, which indicates discomfort, change and disruption denoting the fractures appearing in the unit. In Act 2, we see more of the *Absence* type of imbalance, where Pig and Runt are alone in their individual framing and the space, the other used to occupy is left empty, evoking their absence. From the mid-point of Act 2 to the end of Act 3, we see more incidence of the *Replace* type, where Runt is trying to find a new equilibrium and Pig fails to do so. In the last shot, Runt, alone in the frame is shown centered, no longer to the left or the right, she has achieved her equilibrium and no longer needs a replacement after the death of Mackey and Pig.

In conclusion, we see the balance/imbalance schemata used by the filmmaker, coincide with the narrative changes that happen in the story and serve to enhance the content.

3 Conclusion

Through this study we have observed, that the balance/imbalance schema is indeed at work in the selected text and comes to the fore when compositions from different points in the narrative are compared with each other. To answer the questions formulated at the outset of this paper, the following statements can be demonstrated to be valid in the given context.

(1) The central Balance/Imbalance Schema is visually communicated by first assigning the characters places in the frame to denote a bonded whole and then breaking the rule to evoke discomfort, imbalance and conflict. This is achieved by one of the three discussed types; *Absence, Switch and Replacement* and a combination of all three at times.

(2) The change in the balance schema generally comes about when an important plot point occurs that fractures the unit that Pig and Runt make. And this is evident when one compares the change in framing with the change in the character or story.

(3) The initially established balance schema progressively gets imbalanced to come to a new equilibrium. This is very much in line with how the 3 act structure works. Act 1 is the setup where we find the balance schema, Act 2 is where the conflict starts and imbalance starts to creep into the framing, and Act 3 is where the balance switches and we see the protagonist Runt, come into her own, start to contemplate a life without Pig by her side.

The decision to make these compositional choices in *Disco Pigs* is a very deliberate one and makes sense given the context. Such rules are usually set in place before the production begins and are followed as much as possible, given the constraints of many variables that are subject to change in a complex and dynamic group activity such as filmmaking. The discussed balance/imbalance schema is one of the many cinematic devices that are used in the film, another notable one being the use of colour, which warrants a study of its own.

This paper has demonstrated that embodied balance schema is applied metaphorically in order to express intangible and abstract phenomenon such as love, loss, change, equilibrium in the selected text. The analysis concedes as much and possibly helps to appreciate the complex image making at work in this film.

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An Assessment of Seasonal Variations on Dust Exposure for Mine Operators of Central India

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Abstract India is a mineral rich country the resources of which play a pivotal role in India's economic development. However, this is also accompanied with a significant contribution in fugitive dust emissions with different stages contributing directly as well as indirectly to air pollution and health hazards towards those involved in them. Mine workers as a direct consequence of their occupation are exposed to dust which in turn causes varied forms of pneumoconiosis based on the quantum of dust inhaled. The present study was conducted with an objective of studying personal dust exposure for Heavy Earth Moving Machinery (HEMM) operators working in iron ore mines and its allied plants (Crushing, Loading) in Central India. Trend of seasonal variations on personal dust exposure spread over two years for pre and post-monsoon sampling was also studied. Overall, the personal dust exposure was reported to be within stipulated Directorate General of Mines Safety (DGMS) guidelines. Seasonal trends in case of mining operations viz. Heavy Earth Moving Machinery operators however, indicated that the post-monsoon phase of the second year had lower dust concentrations as compared to the previous year. A similar trend was observed for each category of Heavy Earth Moving Machinery except drills. Contrastingly slightly increased dust concentrations were observed in the pre-monsoon phase of the second year as compared to the first year. Not much of an effect on dust concentrations was however seen on the crusher plants due to seasonal variations.

Keywords Personal dust · Iron ore · Mining · Seasonal variation · HEMM

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1 Introduction

Humans have been engaged in mining since time immemorial. Mining can be divided into five stages viz. prospecting, exploration, development, exploitation, and reclamation irrespective of the type of mining, viz. underground or opencast [1]. Of all the varied ores present, iron ore despite making up just 5% of all the available ores, happens to be one of the most abundantly available minerals [2]. Usage of iron accounts for almost 90% of all metals [3]. As a prime raw material for steel, iron ore is remarkable in its usage for all sectors of our economy, both for construction of infrastructure [2].

The primary minerals of iron are chiefly hematite, magnetite, goethite, and siderite with magnetite and hematite being the most favorable, chiefly because of their high iron content and ease of processing [4]. Usually identified by its deep purple to rusty red coloration [5], iron ore today is mined in about fifty countries around the world with Australia and Brazil being the world leaders in its production [6]. With its huge reserves at 25 billion tones [7], India is ranked fourth overall in the world in terms of volumes of iron ore production. Chiefly found as haematite and magnetite in India, majority of the iron ore reserves of the country are located in Jharkhand, Orissa, Chattisgarh, Karnataka and Goa [8]. While the haematite formations occurs as massive, laminated, friable and powdery form; magnetite occurs as a black or brownish black ore of iron [9]. With the advancement of technology, mining production has increased in leaps and bounds. But there is a flip side to this as well. An increasing rate of is causing ecological imbalances [10], and occupational risks of the mining as a profession too are increasing. Mining involves exposure to adverse environmental conditions viz. excessive noise, poor air quality, etc. which may or may not involve excessive dust generation, etc. [11].

The generation and dispersion of dust is a major issue in mines. Dust is normally generated, when boulders are broken by impact, abrasion, crushing and grinding, or explosions [12]. Surface mining is known to involve drilling and shearing large quantities of minerals which generate clouds of fine particulates in the respirable range [13]. Further HEMMs the unpaved haul roads are also other contributors to dust generation. The resultant dust if inhaled can severely damage lungs, during its passage [14, 15]. The United States—Environment Protection Agency (US-EPA) has defined inhalable dust as that airborne particulate matter, whose diameter is generally 10 μm or lesser. Respirable dust is that fraction of inhalable particles which is capable of passing beyond the larynx and ciliated airways respectively [16]. OSHA, on the other hand, is more specific and has defined the same as aerosols collected by samplers with a 4-micrometer median cut-off [17].

The Indian mines act of 1952 regulates mining in India, whereas the Directorate General of Mines and Safety (DGMS) is responsible for supervising the industry. The American Conference of Governmental Industrial Hygienists (ACGIH) curve, followed in some parts of the world has defined a 50% cut-off at 3 micron with an upper cut-off at 9 micron for dust samplers used in sampling and collecting respirable dust. However the results obtained by samplers based on ACGIH curve do not agree

with the results obtained by instruments based on British Medical Research Council (BMRC) curve which mandate a 50% cut off at 5 micron with an upper cut-off at 7.1 micron for the samplers as it represents in a better way the pneumoconiosis risk from mine-dust. Since the same was also approved by the Johannesburg Conference on Pneumoconiosis (1969), the BMRC curve has been accepted as standard curve for any sampling instrument to be used in Indian mines with a factor of 1.38 being applied to obtain the equivalent Mining Research Establishment (MRE) concentration wherever needed [18, 19]. DGMS (Technical) Circular No. 16 of 1975 has laid down tentative standards for air borne dust wherein it has been recommended that the average concentration of respirable dust in mine atmosphere during each shift to which each miner is exposed at any working point or place shall not exceed 3 mg/m^3, where the free silica in this airborne dust is 5% or less [20].

Research has proven that prolonged exposure to elevated levels of dust is known to stimulate interstitial lung disease [21]. Center for Disease Control and Prevention (CDC) has defined pneumoconioses as a collection of intestinal lung illness caused by inhaling specific clouds of dust and the lung tissue's response to the dust as the primary cause. These diseases typically take many years to advance and manifest. These illness, when they progress in severity, can cause lung damage, incapacity, and fatality [22].

Silica is one of the most commonly occurring minerals in the earth's crust. Exposure to crystalline silica, a basic component of soil, rocks and ores is known to cause silicosis, a progressive, irreversible and often fatal lung disease [23]. Engineering controls to control exposure to dust at its source of generation, wet drilling, dust-proof cabins, use of Personal Protective Equipment's (PPEs), etc., are some measures that can aid in controlling and regulating dust exposure [24].

The rainy season is one of the most challenging seasons for the mining industry. However it is worth noting that both mean relative humidity and mean rainfall show significant negative association with dust fall levels. Findings along the same lines have also been echoed by Giri et al. [26] reported a negative and statistically significant correlation between PM10 with precipitation and relative humidity was observed. Studies documenting increase in fugitive dust concentrations with a decrease in moisture content in the atmosphere give further credence to the above observations [25–27].

In a research carried out by Ghose et al., it was observed that suspended particulate matter (SPM) levels fell within the permissible limit during monsoon [28]. A similar study carried out in 2019 in an opencast limestone mine too echoed similar findings [29]. A study was therefore envisaged to study the effects of the passage of monsoon season, on the alteration in respirable dust levels, if any, for personal samples viz. collected from the breathing zone of the operators. As per IBM reports of 2014–2015, central India is home to more than 29,418 tonnes of iron ore reserves [30] concentrated in opencast mines. The current study was therefore concentrated in a cluster of opencast iron ore mines considering the ease of availability of samples as well as ready connectivity.

2 Materials and Methods

Post identification of the cluster of mines a walk-through survey of the iron ore mines was conducted to identify the operators of the HEMM operators for dust monitoring. The mines selected for the study were observed to have enclosed spaces wherein crushing, screening and loading plants worked in conjunction with the mines. The same were also identified as potential sampling locations for the dust monitoring study, both pre and post-monsoon, with the motive being to evaluate the relative change in dust concentrations, if any, in open and enclosed spaces.

Sporadic instances of unseasonal rains were observed until October 2018. Accordingly, post monsoon dust sampling was done in the month of November, 2018. Pre-monsoon dust sampling was carried out towards the end of March 2019. Indian Meteorological Department (IMD), guidelines were adhered to while defining the sampling periods [31]. Starting from November 2018 until March 2020, there were therefore two numbers each of post-monsoon as well as pre-monsoon periods. While the period of November 2018 and November 2019 (post-monsoon periods) have been referred to as Phase 1 and Phase 3 respectively, the period of March 2019 and March 2020 (pre-monsoon periods) have been referred to as Phase 2 and Phase 4 respectively.

Operators engaged in basic mining activities such as drilling, excavation and loading, dozing and dumper operation were sampled for their exposure to respirable dust in the course of their working shift. Similarly operators engaged in their routine activities at the crusher, loading plant and screening plant too were sampled for respirable dust exposure. HEMMs such as shovel, loader and wheel loader was assumed to be the same category due to their similar operations. A similar principle was adopted for the classification of dozer, motor grader, and wheel dozer wherein the operators were therefore referred to as having similar work profiles. Overall a total of Eighty Four (84) personal dust samples were collected which includes 21 samples from each phase. Samples were collected for an entire working shift, from the entire mining cluster during the post and pre-monsoon seasons each using a DGMS approved dust sampler, viz. SKC make Sidekick-51Ex, wherein a plastic cyclone assembly held within it a 37 mm Polyvinyl Chloride (PVC) filter of pore size 5.0 μm for collecting respective samples of respirable dust. The sampler-cyclone assembly was attached to the worker and within his breathing zone such that it did not interfere with his work or safety [20, 32, 36] at flow rates calibrated to 2.2 L/min using a rotameter represented in Fig. 1.

The concentration of collected respirable dust was got post-calculation of difference in weights of the PVC filter paper pre and post-sampling. Sidekick MTX51 has a correlation factor of 1.13 with MRE 113A concentration. Hence results obtained by dividing the difference by 1.13 to get the MRE equivalent concentration in mg/m^3 [32]. Details of the personal samples along with the reported MRE equivalent concentration for the pre and post-monsoon seasons taken in Phase 1 to Phase 4 are presented in Table 1. The statistical analysis on the collected data was carried out using Graphpad Prism 9 software.

Fig. 1 Attaching personal dust sampler to a HEMM operator

Table 1 MRE equivalent for personal dust for operators of HEMMs and Equipment's (n = 84) for Phase 1 to Phase 4

HEMMs/Equipment		**Phases** Mean ± SD (Range)			
		Phase 1	Phase 2	Phase 3	Phase 4
HEMMs	Shovel/loader/wheel loader (3)	0.92 ± 0.14 (0.76–1.04)	0.67 ± 0.29 (0.35–0.91)	0.39 ± 0.05 (0.34–0.44)	0.76 ± 0.10 (0.66–0.86)
	Dozer/motor grader/wheel dozer (3)	1.18 ± 0.45 (0.73–1.7)	0.55 ± 0.12 (0.44–0.68)	0.21 ± 0.05 (0.16–0.26)	0.73 ± 0.52 (0.13–1.04)
	Drill (3)	0.58 ± 0.14 (0.46–0.73)	0.60 ± 0.21 (0.43–0.84)	0.46 ± 0.19 (0.25–0.58)	0.85 ± 0.15 (0.75–1.02)
	Dumper/water tanker (3)	0.86 ± 0.28 (0.53–1.03)	0.53 ± 0.04 (0.50–0.58)	0.31 ± 0.04 (0.27–0.34)	0.77 ± 0.25 (0.49–0.97)
Allied plant	Downhill (3)	1.07 ± 0.48 (0.65–1.59)	1.15 ± 0.40 (0.74–1.54)	0.57 ± 0.28 (0.32–0.87)	1.22 ± 0.32 (0.93–1.57)
	Crushing plant (3)	0.82 ± 0.06 (0.75–0.87)	1.07 ± 0.64 (0.39–1.66)	0.66 ± 0.32 (0.29–0.85)	1.09 ± 0.33 (0.81–1.45)
	Loading plant (3)	1.35 ± 0.15 (1.18–1.45)	0.87 ± 0.29 (0.58–1.16)	0.43 ± 0.17 (0.31–0.62)	0.93 ± 0.24 (0.65–1.07)

*All values for dust are represented in mg/m^3

3 Result and Discussion

The MRE equivalent for personal dust concentrations in HEMMs operators as well as allied mining plant for an 8 h operation for Phases are presented in Table 1. Overall, the MRE equivalent for all of the phases investigated was found to be significantly below stipulated DGMS standards [33].

It was observed that the operators of the loading plant were exposed to the highest dust concentration in Phase 1 wherein drill operators had the lowest exposure. In Phase 2, the highest dust concentration was found among Downhill operators while lowest dust concentration was found among Dumper/Water Tanker operator. Operators of crushing plant had the highest mean dust concentration in Phase 3 wherein

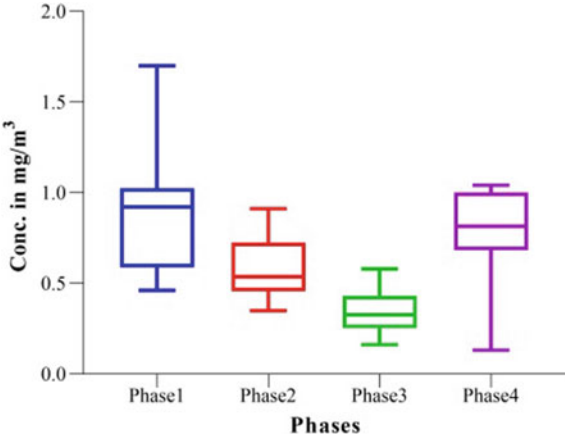

Fig. 2 Dust concentration in the four phases for HEMM operators

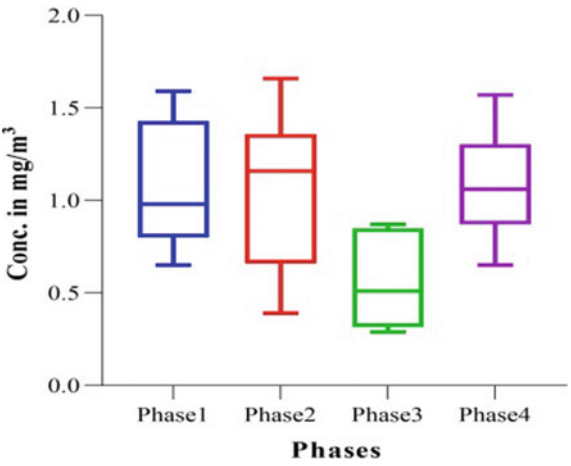

Fig. 3 Dust concentration in the four phases for operators of allied plants

operators of the Crushing Plant had the highest mean dust concentration. Operator of Dozer/Motor Grader/Wheel Dozer had lowest mean dust concentration and operators of Downhill were observed to have the highest mean dust concentration in phase 4. Figures 2 and 3 depicts the dust concentrations in four phases for the different personnel sampled (mines and allied plants). An overall overview of the results obtained in the four phases is shown in Fig. 4.

3.1 Statistical Analysis

The obtained data were subjected to statistical analysis using a one-way ANOVA test to determine significance in variance and investigate relationship. Table 2 shows the

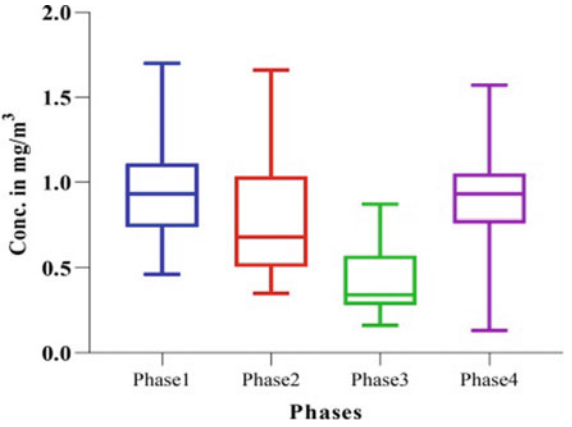

Fig. 4 Overall dust concentration levels for the four phases for mines studied

Table 2 Results for ANOVA applied on MRE equivalent for HEMMs and Equipment operators in Phase 1 to Phase 4

ANOVA table	*P*-value
Treatment for HEMM operators (Between all phases)	$P < 0.0001$
Treatment for operators at plants (Between all Phases)	$P = 0.0042$

results of One-way ANOVA on dust values obtained from operators of HEMMs and allied plants for all Phases. Benferroni's multiple comparison post hoc test was used to analyze the variance across phases and test significant levels between consecutive pre-monsoon and post-monsoon seasons. The findings are shown in Table 3.

The ANOVA analysis hints at a statistically significant difference in MRE equivalent concentrations for HEMM operators in Phase 1, Phase 2, Phase 3, and Phase 4 with $P < 0.0001$ (< 0.05). Similarly, with $P = 0.0042$, the ANOVA analysis suggests

Table 3 Results for Bonferroni's multiple comparison tests

Operators	Bonferroni's multiple comparisons tests	Mean diff	95.00% CI of diff	Below threshold?	Adjusted *P*-Value
HEMMs	Phase 1 versus Phase 2	0.2958	0.07183 to 0.5198	Yes	0.0074
	Phase 3 versus Phase 4	− 0.4350	0.6590 to − 0.2110	Yes	< 0.0001
Plant	Phase1 versus Phase2	0.05111	− 0.3170 to 0.4192	No	> 0.9999
	Phase3 versus Phase4	− 0.5256	− 0.8936 to − 0.1575	Yes	0.0041

that there is a statistically significant variance in MRE equivalent concentrations for operators at plant in all phases.

A Bonferroni's multiple comparisons test for HEMM operators for Phase 1 versus Phase 2 and Phase 3 versus Phase 4 indicated a significant difference in the mean MRE equivalent, as shown in Table 3. However, a statistical significance of $P < 0.0001$ was found between Phase 3 and Phase 4. A Bonferroni's multiple comparisons test represented in Table 3 for plant operators for Phase 1 versus Phase 2 and Phase 3 versus Phase 4 revealed that there is a significant difference in the mean MRE equivalent for Phase 3 versus Phase 4 but it was not observed to be significant for Phase 1 versus Phase 2.

Kakoli Karar 2006 reported higher concentrations of dust during winter and lower concentrations during the monsoon [34]. This particular study has attempted a similar study in mines wherein, it was observed that dust levels were on the higher side in the pre-monsoon period as compared to the post-monsoon period for 4 phases of mining operation. The HEMMs such as a Shovel, Loader, and Wheel Loader are usually in operation for shoveling, loading, etc. These operators usually work under closed cabin conditions in lines with prescribed norms for dust control. The maximum mean dust concentration for these operators was observed in Phase1 with the minimum being observed in phase 3. It can therefore be deduced that seasonal variations due to monsoon were observed in dust concentration for Phase 3 and Phase 4 comparatively. Contrastingly dust concentration in post-monsoon viz. Phase 1 was found higher than in pre-monsoon viz. Phase 2. This could be attributed to dust control measures applied in mining operations. Other reasons for this inconsistency could include meteorological parameters such as temperature, wind speed, wind direction, relative humidity, etc. [35] since these have been reported to play an inhibiting role in dust dispersion.

For the operators of Dozer/Motor Grader/Wheel Dozer, it was observed that the mean dust concentration values for each phase varied with varying seasons and operational conditions. In phase1 whiskers dominated the lower side whereas phase 3 reported equidistant whiskers. The suppression of dust concentration in Phase 3 might be due to rainfall occurring before this study period. Not much of a significant difference was observed in the mean dust concentration of phase 2 and phase 4. These classes of HEMMs mostly operate in closed chamber conditions. Due to this, seasonal inconsistency can be seen in the results got post sampling and the effect of monsoon might not be necessarily seen as well. Whilst guidelines suggest the use of enclosed Cabins for HEMMs for the prevention of dust exposure, it has been observed in the current study that they prevent a truer analysis of dust exposure patterns with the consequent seasons.

The drill mostly operates in wet conditions due to which variation in seasonal trends could not be ascertained. Operation of drills has a routine of operating from within the cabin as well as occasionally getting out monitoring the progress of drilling. The maximum mean dust concentration in the drill was observed for Phase 4 whereas phase 3 reported minimum dust concentration. Similar results have also been reported by Mankar et al. [29].

HEMMs such as Dumper and Water Tanker operate in affixed routines with well-defined movement in a closed chamber operational condition. Comparative observation of their dust concentrations hints at a lower mean dust concentration with a progression in phases, the only exception being a marginal higher dust concentration in phase 4. While it cannot be neglected that water sprinkling plays a major role in lowering dust levels it should also be pointed out that dumper, water tanker operators are usually positioned in closed operator cabins throughout their shift thereby hinting at lower dust concentrations.

Crushed iron ore material is transported through a closed downhill conveyor system to screening downhill through the conveyor system to the secondary stockpile of the existing screening plant. Operations in downhill involve transportation of ores from mines to loading plant. Since these activities occur in closed shades effect of the environment hardly affects dust dispersion. The maximum mean dust concentration for the downhill was observed in phase 4 whereas the minimum was observed in phase 3. Dust concentration for operators downhill seemed to follow seasonal trends. Phase1 reported a lower concentration as compared to Phase 2. A similar trend was also observed between Phase 3 and Phase 4. These values represent a significant correlation between dust dispersion and pre-monsoon and post-monsoon season. Karar 2006 in their study have reported an inverse correlation between dust concentrations and rainfall [34].

The crushing plant is mainly involved in crushing and reducing ore size to − 150 mm. Maximum mean dust concentration was observed in Phase 4 whereas minimum mean dust concentration was observed in Phase 3. Values of dust concentration for operators in crushing plants seemed to follow seasonal trends significantly. Phase 1 showed a lower concentration than Phase 2. And Phase3 showed lower values of dust concentration than Phase 4. The trends are observed to be similar to those that have been reported in dust levels for operation in downhill.

Stacking and reclamation coupled with loading in freight train activities are carried out in the loading plant. There is therefore dispersion of a large amount of dust in this area. Overall the maximum dust concentration was observed in Phase 1 whereas the minimum mean dust concentration was observed in Phase 3. Overall it was observed that mean dust concentration for personal dust samples of operations in loading plant followed a trend similar to that of the. Crushing plant and Downhill except for Phase 1.

With regards to dust concentration for the HEMM operators, there is observed in Fig. 2 that Phase 1 reported a higher concentration than phase 2 which resulted in a non-significant correlation with the monsoon season. Phase 3 showed a lower concentration than Phase 4 showing a positive correlation with the monsoon period. Levels of dust concentration in Phases 3 and 4 were somewhat similar as compared to the other phases. Whilst lower concentration in Phase 3 could be due to seasonal conditions post-monsoon it should also be appreciated that the application of various preventive measures from mine management has limited dust levels within permissible limits.

4 Conclusion

This article has focused on the seasonal variation of personal respirable dust exposure in a cluster of iron ore mines in central India. Sampling was carried out for operators working in HEMMs and Plant for studying seasonal variations on respirable dust concentrations. Dust concentrations were observed to be on the higher side in HEMM operators as compared to those in plant operators. Significant and occasional spurts in mining to meet routine targets could be one of the prime reasons since pre-monsoon season coincides with the financial year ending and therefore a period of peak productivity. These peak operations in mining therefore mostly affected mean dust concentration in HEMM operators more than plant operators.

The results in HEMMs have followed a seasonal trend except in Phase 1 which has shown a slightly high dust concentration in the dust. The HEMMs such as Shovel (Shovel/Loader/Wheel Loader), Dozer (Dozer/Motor Grader/Wheel Dozer), Dumper (Dumper/Water Tanker) have shown a slight high dust concentration in Phase 1 than Phase 2 and followed a seasonal trend in remaining Phases viz. higher concentrations in pre-monsoon and lower post-monsoon. This inconsistency in trends could be due to the peak operations in mining dust concentrations [36]. On the other hand, dust concentrations for drill operators were observed to show a trend in dust concentration seasonally.

The result in dust concentration for plant operators shows a correlation between pre-monsoon and post-monsoon periods. The dust concentration has been observed to be higher in the pre-monsoon period and lower in the post-monsoon period. The results are similar for every plant in mine except in the loading plant. A similar trend was observed in the HEMMs category where various HEMMs have shown higher concentration in phase 1 only to taper down following the adoption of dust suppression measures and seasonal variations. Loading plants also have shown a slightly higher value in Phase 1 than Phase 2 only to follow a seasonal trend in the remaining phases. This result may be due to a production peak in that phase as compared to other phases. The dust concentration may also be affected due to the amount of rainfall, wind speed, temperature, relative humidity, etc.

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Understanding the Experiential, Experimental and Spirited Aspects of Typography

Mohammad Shahid

Abstract Using sign and symbols as a mode of communication is a very old tradition. Our ancestors have used it efficiently to communicate and share thoughts between each other. In the later period, along with the evolution, different tools and techniques also developed to support and enhance the communication process. Use of type or letters was one such development in the history. This helped to translate language into a written form which can be preserved and share with wider audience. Across the timeline, designers and researchers have experimented with the different attributes of letterforms to communicate effectively. Through literature review and classroom case study, this paper has aimed to explore different approaches which can be used to make typography more experiential and spirited in the classroom setup as well as design projects.

Keywords Experimental typography · Environmental typography · Type as a product · Type and space · Playful learning · Practice based research

1 Introduction

Typography is a constant evolving discipline. Domain experts and researchers have given several definitions to it. According to Ellen Lupton, "Typography is what language look like" [1]. It is an art of putting verbal language in a written form to communicate an idea or a thought by arranging type while giving emphasis to legibility and readability of the content. To understand the experiential and spirited aspects of typography, it is important to look at the history and highlight the major development happened across the timeline.

The earliest known type was a written symbol on clay tablets. These symbols were created by making impressions on clay. It was used for record keeping by the Sumerians before the invention of writing. The Sumerians also invented Cuniform, a very early writing system which uses the wedge-shaped mark on clay tablets around

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3000 BCE. By 1450 BCE, they started using papyrus stem as a base to write information in the form of a book. Rudiments of the serif letters and sans-serif capitals appeared around this period. Serifs and sans-serifs are two very basic categories of typefaces from which all other typefaces are derived. According to Robert Bringhurst unserifed (also called sans-serif), letters have a history at least as along as serifed letters. He mentioned that 'unserifed capitals were first appeared in the earliest Greek inscriptions' [2].

The modern development in typography took place in the Western world. Johann Gutenberg is credited with inventing movable type in 1450 in Mainz, Germany. During this period, Renaissance helped in spreading the humanist philosophy. It has established a belief in human dignity and worth, a spirit of individualism, and a shift from religious to secular concerns. Humanism inspired and encouraged typographers to create a variety of typefaces in this era. For examples decorated initials at the head of each chapter become the part of book's body content. These initials showed an illustrative style having intricate creepers and floral patterns making it spirited in terms of creating impact and setting the tone for the chapter. This was also the time when uses of italics become evident. One of the examples of its early use is Blodius Palladius written *Coryciana*, 1524 [3]. It is a collection of Latin poems admired for its printing quality.

The beginning of the nineteenth century brought a dramatic impact on typography and the graphic arts. New technology radically altered printing, resulting in new typographic forms and images. Brash display typography becomes evident overwhelming the old-style letters. Fat face, being the first in this display typeface, was introduced by Robert Thorne in 1803. He was also responsible for inventing the term Egyptian to describe what is known today as the Slab Serif. This style created the base for contemporary display lettering [4]. Fat face typeface was later followed by Egyptians in 1815 by Vincent Figgins and sans serifs in 1816 by William Caslon IV [5]. Egyptian, Fat Face and Sans Serif were the three basic forms of display letters introduced in the early years of the nineteenth century. Along the time, hundreds of variants were produced based on these three versions. Before this variant, most of the printing text was dominated by roman letters which were monotonous. Availability of many font options brought a revolution in the printing industry and changed the visual language of bills, posters, labels, and letterheads. It also created an opportunity to use different typefaces in one single bill or poster to create hierarchy and make composition interesting.

By mid-nineteenth century designers also started experimenting with perspective in typography. Vincent Figgins was the leading name who designed perspective type in 1836 (Fig. 1).

Industrial revolution resulted into a huge demand for advertising which in turn increases the demand for large-scale letters that could grasp attention in the visually crowded urban space [1] and this was mostly achieved using Wood Type. By the twentieth century, the technical and scientific progress resulted into many cultural movements and new trends of thoughts across the globe. These were Art and Craft, Art Nouveau, Cubism, Futurism, Constructivism, Suprematism, Expressionism and Dadaism. Art Nouveau played a key role in the development of modern architecture

Fig. 1 Type in perspective designed by Vincent Figgins, 1836. *Source* [6]

Fig. 2 Art Nouveau letterform on German art magazine *Jugend*, 1900. *Source* [6]

and new typography. Characterized by curved lines (Fig. 2), Art Nouveau initially appeared as a decorative art movement. It had a long-lasting effect on printing. Its letterforms origin lay with roman letters. This movement brought the new freestyle in English typography and had its influence till the 1920s.

Dadaism was another significant movement in the experimental typography. It was credited for using typographic symbols in painting. Painters from Dada regarded typography as an 'uncontaminated' medium. Dada painters gave stimulus to typographer by using the symbols in unconventional ways to produce a kind of childish anarchy [5]. They rejected the axial symmetry, traditional margins, serifs and decorations in their typography. The typographic work from this period shows artist's concern about social injustice and discrimination.

Abandoning capital letters from the typography or texts came with the thought of Bauhaus. New typography from Bauhaus brought mechanical logic to typography, mainly synonymous with the German style of working. Overview of typography evolution cannot be complete without mentioning Jan Tschichold. Trained in both calligraphy and lettering, he was the first person who formulated the principles of new typography and made it understandable to everyone. The characteristic features of this were freedom from the tradition, geometrical simplicity, contrast of typographical material, exclusion of any ornament not functionally necessary, attention

to type size which can be mechanised, use of primary colours and photographs for illustrations [5].

Though, after invention of movable metal typeface, typography field witnessed a steady development. On many occasions, designers have used just text to communicate the idea. However, many times, graphical elements in the form of icon, index, symbol or metasymbol have been explored in combination with letterform to create an effective visual-verbal message. The connotative power of image and text together strengthen the overall meaning creation. Talking about the power of text and role of visual-verbal synergy, Roland Barthes states that, "Formerly, the image illustrated the text (made it clearer); today, the text loads the image, burdening it with culture, a moral, an imagination. Formerly, there was reduction from text to image; today, there is amplification from the one to the other" [7]. That means, "image does not illustrate the text; it is the text which amplifies the connotative potential of the image" [8].

Though, the literature on typography is majorly from the western world, typographic tradition in India was equally rich. However, there are hardly any literature available on this and information is scattered here and there making it difficult for excess. India has a rich manuscript tradition from palm leaf inscription to the paper. Typography/lettering art has been explored from calendar art, matchbox cover, truck art, shop signs and film posters. Titles in film posters are significant artifact to understand the persuasive nature of typography [9, 10]. The expressive and experiential typography is quite evident in street signboards where lettering has been done by street painters. Many designers such as Hanif Kureshi and Sarang Kulkarni are trying to digitalize this vanishing vintage typography [11]. They are transforming lettering style of street artists into digital typefaces. The result is quirky and shows Indian richness in terms of intricacy, decoration and colourfulness (handpaintedtype.com).

2 How It Works as Experiential and Spirited?

Typography has a power to communicate ideas straightforward without any ambiguity. Apart from the conventional two-dimensional printed form, designers have explored it in three-dimension with texture and perspective to make it expressive and impactful. This section explores these approached to understand how it works as experiential and spirited.

2.1 Typographic Resonance

Berger [12] claimed that "Seeing comes before words. The child looks and recognizes before it can speak [12]." This is also true for an illiterate viewer who is unable to understand the meaning of a written word. Visual resonance in graphic communication is important for effective and successful message communication irrespective to the individual's literacy level. Its application exaggerates the message and enhances

the experience. In graphic design, this is achieved through different visual qualities of image and text. "Typeface selection, scale and cropping of images, the denotative and connotative properties, colour, and spatial organisation all play roles in the overall resonance of the design [13]." Typographic resonance is an effective medium to establish a relationship between typeface form and semantic content. Philip B. Meggs writes

> Typographic resonance is generated by the cultural, stylistic, and connotative properties that typefaces possess in addition to their function as alphabet sign. A typeface gains these resonant qualities through historical tradition, associations relating to its typical use, and its optical properties. [13]

In typography, "form relates to rendered letters, typefaces, words, or logotypes" [14]. In any typographical application, individual letters act as a building block where its form and style contribute in suggesting mood and emotions. Any constructive meaning can only be generated through the understanding of message hidden somewhere in the style and structure of the individual letters/fonts [15]. In Jason Tselentis own words:

> Like people, places, and things, font themselves can possess denotative and connotative qualities. An objective eye can look at a font and make visual judgments beyond simple serif versus sans serif, bold versus light or wide versus condensed. [14]

In typography, resonance and expression can be achieved by manipulation through colour, form, size, shape, thickness/stroke weight, texture and spatial organisation of letters. *Type effects* such as outline, drop shadow, dimensional block shadow and dimensional letterface are other ways to create impact and exaggerate the meaning [16]. Inclined letterform can give a sense of activeness [17], whereas weight can help to create visible impact through the contrast thickness and boldness [18]. For example, in Fig. 3, variation in stroke weight has been used to emphasise the two words of opposite meaning. In 'whisper' stroke weight conveys a sense of lightness whereas in 'shout', it reflects the boldness. Here in both cases, the meaning is reinforced by suitable font size and style.

Fig. 3 Typographic resonance. *Source* [13]

2.2 *Juxtaposition and Fusion of Image and Text*

To make it more experiential, designers have adopted other approaches such as juxtaposing and fusing type and image. In juxtaposition, image and text are combined to intensify the communicative power of a composition [13]. One can find frequent use of such exploration in commercial advertisements including movie posters. Even one can find this type of use as drop cap letters in early time writing like in medieval manuscript. Sometimes juxtaposition of type and image create a cause-and-effect relationship where both complement each other in meaning creation [13].

Also known as figurative typography, many times type and image are fused together to exaggerate the meaning. Painters associated with futurist movement in Italy believed that "the different aspects of vision could be combined in one 'process of interpenetration—simultaneity-fusion'" [19]. Simultaneity is defined as the fusion of unlike form so that they can occur at the same time. In the twentieth century, artist and graphic designers associated with different art movements especially the futurist and cubism has utilised this *simultaneity* to a great extent in their artworks. In typography, one can find this fusion in terms of image as a letter, letter as an image, word as an image and text type as an image.

An image can substitute a letterform in a word. For example, in the logo of *Talkmore* (Fig. 4), company symbology in the form of quotation mark has been used to replace letters A and E. The company sells mobile phones and mobile phone accessories. The straightforward and clever use of quotation mark as a symbol gives a unique visual look to the logo.

In many cases, letterform can be manipulated so that it can act as both a letter as well as an image at the same time. By doing this, it helps in enhancing connotative and denotative meaning to a certain extent. In Fig. 5, Families logo designed by Herb Lubalin in 1980, the lowercase '*i*' and '*l*' have been modified in such a way that visually it presents a group of family members. The tight spacing between letters and different size symbolically relate with a family with different age group in a close bonding. The logo shows that simultaneity between image and letter can be achieved by manipulating letterform (Fig. 5).

Meaning has been also expanded and enhanced by altering and manipulating the visual form of a word. Logo for Amul milk by Yashwant Chaudhary is a classic example where *milk* word has been transformed into an icon of dairy cattle. The whole logo designed using white space, in rounded fat letters perfectly relate with the colour of milk and nutrition value associated with it (Fig. 6).

Fig. 4 *Talkmore* by Nido. *Source* [20]

Fig. 5 Families logo, 1980 by Herb Lubalin. *Source* http://www.logodesignlove.com

Fig. 6 Logo for Amul milk products by Yashwant Chaudhary. *Source* http://www.designinindia.net

Many times, whole text type is set in a shape that becomes a sign or icon. Otto Storch is known for his expertise in making pictures out of type also known as 'figurative typography'. He believed that text type should be an integrated component of the illustration instead of keeping it as a separate form. A spread designed for *McCall* magazine in 1959 shows an example of figurative typography where he has visualised whole text as an image [21] (Fig. 7).

2.3 Understanding from Studio Projects

This section discusses the different studio work where students from both product design as well as graphic design were encouraged to experiment with the experiential and emotional aspect of typography to understand the letter form in a playful way. The participation and involvement were encouraging, and the task made students immersed deep into the subject.

Latter Patterns and its Visualization into a Product. Throughout the evolution, hundreds of beautiful typefaces got designed. Designers and artists have used these typefaces both in conventional as well as progressive way to express emotions and

Fig. 7 Figurative typography, spread from *McCall* magazine, 1959 by Otto Storch. *Source* [21]

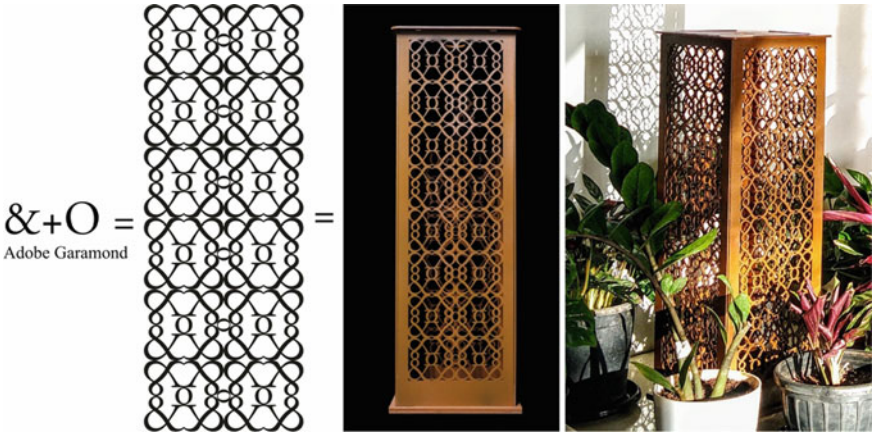

Fig. 8 Stages showing transformation of letter '&' and 'O' (Adobe Garamond) into a lamp shade. *Source* Author

ideas across the timeline. If explored in right way, some of these fonts can be transformed into spirited products which can be used as a part of space and architecture. As shown in Fig. 8, beautiful design of ampersand character and letter 'O' from Adobe Garamond has been to create a pattern and later transformed into a product using laser cut technique.

As a studio task, students were given with a brief to look for a letter of individual interests in the surrounding environment. After selecting the letter, they must simplify the form into flat 2D shape. As shown in Fig. 8, students were asked to create a pattern

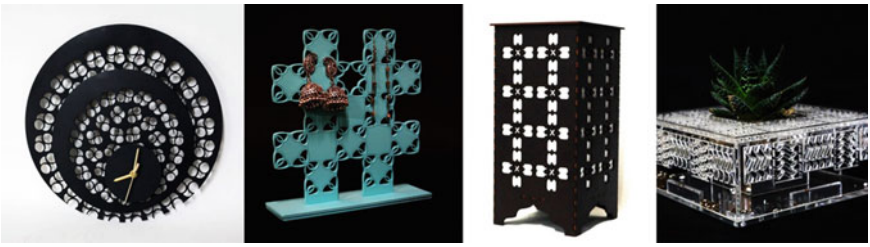

Fig. 9 Letter pattern visualized as a products by M.Des Graphic Design, 2019–21 batch students (from left to right; Sayali, Siddhi, Nidhi and Ishani) at MITID Pune

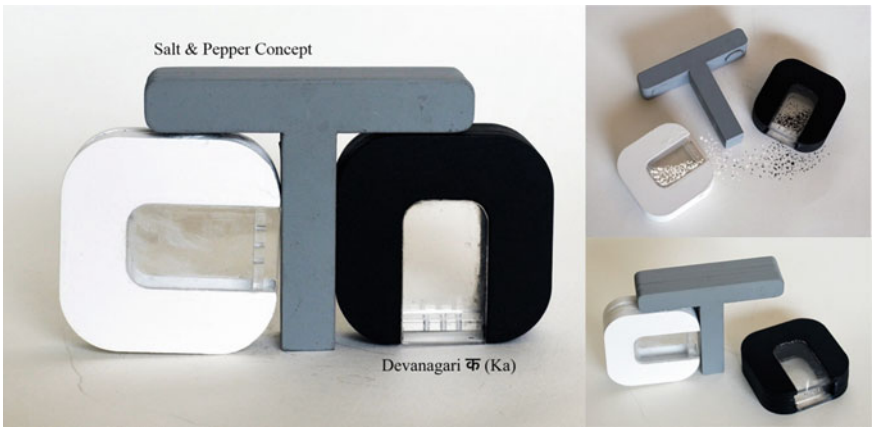

Fig. 10 Devanagari letter क (ka) visualized as a product by Kashish, a B.Des Product Design student at MITID Pune

using the 2D letter and translate it into a product using any material. This resulted into better understanding of letterform along with several unique and innovative products (Fig. 9).

Individual Letter as a Product. India is very rich in terms of regional languages and scripts. Literature have revealed that letters can be visualized as interesting 3D products. With similar assumption, students were briefed to select a letter from any Indic script and visualize the same as a product as a part of space and installations. Again, outcome from the class shows lively and engaging explorations. One example where letter क (Ka) was visualized as a *Paper and Salt* dispenser also provide a scope to the user to play with its form (Fig. 10). The two loop of letter 'Ka' has been attached with *Shirorekha* (upper horizontal line) using magnet and can be detached and used as a dispenser on dining table.

It was observed that this kind of experimental typography modules encourage students to explore and learn the subject in a fun way and can be very effective in terms of understanding the letterforms. In another example, letter म (Ma) and

Fig. 11 Devanagari letter म (Ma, by Tukaram), ळ (La, by Harshit) and प (Pa, by Nilesh) are visualized as an artifact by Product Design students at MITID Pune

ळ (La) has been visualized a chair and table, whereas letter प (Pa) and ट (Ta) are explored in a single product which can be rotated/flipped and visualized into two letters simultaneously. This kind of playfulness opens the possibilities of using letters as a part of learning process in the school level where letters (as shown in Fig. 11) can be installed in the school premises and kids can interact and learn while playing.

3 Conclusion

This paper started with an intention of understanding the experimental, experiential and spirited aspects of typography. Literature revels that researchers and designers have utilized different approaches to achieve this goal. Examples from the past and classroom assignments also validate this assumption and reveals that typography can be made more immersive and experiential. Apart from the conventional typography, there are different ways to make this subject interesting as well as engaging for the students. To do this one must open the mind and look in surroundings for the inspiration. If it is done in right way, experimental typography can reveal the experiential and spirited aspect of typography and can become an effective tool to learn and understand the letterform and its unique features. The classroom projects also open the possibilities of designing letters in such a way that it can make learning more playful and engaging. However, in case of visualizing letters for tangible functional products, it might have limitation.

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A Questionnaire Analysis for Customizing Bicycle Design Based on Musculoskeletal Disorder Discomfort Level

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Abstract Cycling, which was once used solely for transport purposes in past decades is now being majorly used for recreation, exercise, and as a sport. Cycling improves cardiovascular fitness by reducing body fat levels. In recreational aspects, there are organized rides, cyclo-tourism (which involves exploration by bicycle), Mountain Biking (known to be Downhill mountain biking). To have considered it as a sport, cycle racing is common for almost a century all across the world. In this study, we have analysed musculoskeletal disorder (MSD) for different genders of bicycle riders, along with the different types of bicycle design for the users in the southern region of India. Methods: 129 Indian participants (89 males and 40 females) of various ages were considered. A questionnaire was created and surveyed among the participants regarding the areas of pain during cycling (based on the RGB pain score of 0–5) for different types of bicycle designs. Results: Based on the statistical analysis with the acquired data, it is found that females suffer pain more than males notably in the region of thighs and knee. Analysis about the effects on the participants based on the different cycle designs such as Gearless, Geared, Rigid frame, Single suspension, Mountain bike used was also performed. As a result, single suspension bicycle users exhibited high pain scores. These results indicate that appropriate ergonomics issues are to be considered to develop a better bicycle design.

Keywords Bicycle design · Ride comfort · Musculoskeletal disorders (MSDs) · RBG pain score · Questionnaire

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1 Introduction

Poise, cheer, well-being, pleasure, and convenience are the integral hallmarks of "comfort". According to Pineau [9], comfort is defined as everything whichever contributes to the well-being and convenience of the material aspects of life. The level of comfort is not the same for all individuals. Limited product specification in the material domain extended its views on the abstract domain that encompasses informational and psychological facets [15]. But, the recent ergonomic studies have elicited various material phases of human comfort along with their physiological aspects. Ayachi [2] has analysed using multidimensional statistical and found that frame, saddle, handlebar, and environmental facets viz., type of road, weather conditions, and cyclist's position, adjustment, body parts are various factors influencing the cyclist's comfort. Swart and Holliday [13] investigated various optimal configurations through dynamic assessments of the bicycle using kinematic measurements to analyse intrinsic factors that may affect the bicycle configuration and performance. Further, research carried out by Atkinson [1] objectified the environmental facets, the interrelationship between these factors and schematic model, and suggestions for future directional optimization of the bicycle. Postural configurations of the bicycle were also analysed along with discomfort levels of using bicycles at various facets and phases [5]. A retrospective study on factors associated with injury, discomfort, and pain perception among cyclists was studied by Priego Quesada [10].

This paper concisely gives an overview of different bicycle design optimization based on musculoskeletal disorder discomfort levels. The present study rivets on the musculoskeletal disorder discomfort level of various body regions over different cycling. A questionnaire survey was conducted to gather information from approximately 120 participants to analyse the discomfort level. Balasubramanian [3] has stated that an ergonomic study is very essential in planning for ergonomic inventions and targeting productivity along with quality improvement.

This questionnaire aims to analyse the following health issues for bicycle users:

1. What are the discomfort levels aroused between different gender specificity viz., male and female?
2. What are the various musculoskeletal discomforts of using different mechanical designs of the bicycle?
3. What are the various discomfort levels aroused in a different region of the body?

2 Materials and Methods

An online survey was conducted between 19 March 2021 and 13 April 2021. Responses were recorded using a Google form. Respondents shared their responses through different tools viz., (i) Facebook, Instagram, and other social media, (ii) Invitations sent via email identity. On a whole 129 people responded. The questionnaire consists of two sections and each section was described below.

Table 1 Pain-score criteria and their grades

Criteria	Pain score
No pain	0
Pain while more than average workout time	1
Mild pain	2
Moderate pain	3
Continuous pain	4
Severe pain	5

Section 1: focuses on the basic personal information including demographic information, age, gender, handedness, height, weight, etc., the most participated gender is male constituting 68.8% in total and female of 31.3%. 93.8% of the participants were right-handed. 44.5% employed and 42.2% students majorly participated.

Section 2: information on different form factors that include hours of cycling per week, the type of cycle, and the form of cycle been or being used. This section is structured in a way such that the musculoskeletal disorder over various types and forms of bicycle users can be analysed. The Physiological parametric responses were further divided into three sections according to Upper, Lower, and shoulder to palm body regions. Respondents were asked to mark the score on the scale of range 0–5, where the range metric is specified in the form. Pain score was collected shoulder to palm body regions (which encompasses neck, shoulder, elbow, forearm, wrist, and palm); upper body regions that encompass the spine (backbone), chest, hip, and abdomen (stomach); lower body regions that encompass thighs, buttocks region, knees, calf (leg triceps), and foot.

This study is based on subjective measures using Rehabilitation Bioengineering Group Pain Scale (RBGPS). The ratings were converted to RBGPS scale scores with different bicycle form categories. In the absence of integrated ergonomic assessment tools, Balasubramanian [3] have proposed a composite measure called the RBG pain scale as shown in Table 1 that allowed them to measure ergonomic assessment in terms of several factors.

In each section, the questions were structurally organised so that it would be easy for a respondent to give his/her response.

3 Results and Discussions

All 129 participants completely recorded their responses according to the section and subsections as directed in the form. Figure 1 depicts the data chart with basic information that was collected during the survey. The information inferred from Fig. 1 were that, there were 89 males (68.8%) and 40 females (31.3%). On a whole 93.8% of responders were right-handers and the major group of responders was working employees (44.5%) and students (42.2%).

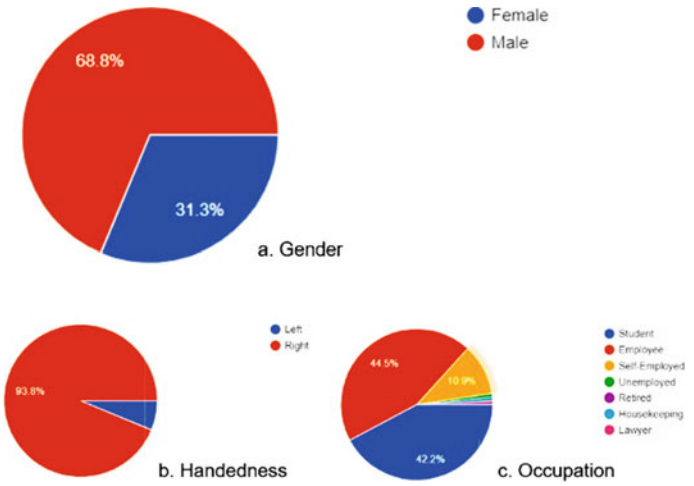

Fig. 1 Basic information

Firstly, the pain score was statistically analysed for all three physiological sections altogether for two different categories based on gender, i.e., male versus female. Figure 2 clearly shows the difference in pain scores between males and females over various body regions. It is inferred that the pain score is significantly ($p < 0.05$) high for the female when compared to the male. Adding to that, regions of the thigh, knees,

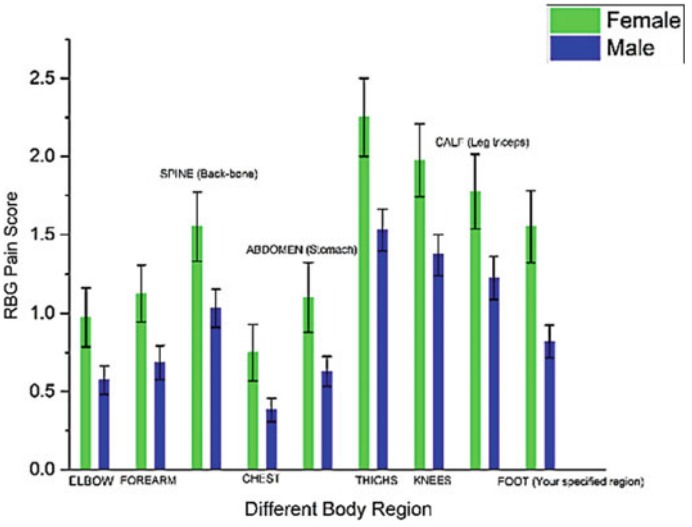

Fig. 2 The mean and one standard error value of RBG Pain scores between males and females over various body regions

calf, foot, and spine constitute the major high pain score metrics on the RBG scale (>1.5). Therefore, the physiological discomforts are more for females in all regions.

Further physiological analysis was made amongst different cycle design users. The major cycle designs are categorised into broad six categories and analyses were made within these six categories.

- Geared bicycle,
- Gearless bicycle,
- Mountain bike,
- Rigid Frame, Geared bicycle,
- Single suspension bicycle, and
- Single suspension, geared bicycle.

Adding to different categories, physiological analysis was divided into 3 main categories concerning body regions and the cycle design groups are its sub-category.

Streisfeld [12] examined the relationship between body positioning, spinal kinematics, and muscle activity in active cyclists. The spine is a major skeleton and the muscles associated with it are *spinalis cervicis*. It is inferred from Table 2 that the respondents using a single suspension bicycle design have significantly ($p < 0.05$) high RBG pain score (~2.1) when compared to the rigid frame-geared bicycle users (~0.3), having their pain score values twice less than the lowest scale metric (=0.8).The other types lie within these range. On comparing our results with the work carried out by Srinivasan and Balasubramanian [11], they have used a 10-point visual analog scale, from which they have inferred that the subject group has a mean value of 6.80 which is evident showing that there is pain increment in the spine.

Hip, yet another important body region for ergonomic analysis. Hip flexors are the major muscles that are involved during cycling. From Table 2 it is inferred that a single suspension bicycle design significantly ($p < 0.05$) (~1.9) exceeded the maximum limit (=1.4) of the RBG pain score. Once again, same as spinal analysis,

Table 2 The mean and one standard error value of RBG pain score analysis amongst different cycle design users

S. No.		Cut off range	Geared	Gearless	Mountain bike	Rigid frame, geared	Single suspension	Single suspension, geared
Upper body region								
1	Spine	0.8–1.8	1.4	1.2	1.0	0.3	2.1	0.9
2	Hip	0.4–1.4	1.1	0.7	1.1	0.2	1.7	0.9
3	Chest	0.3–1.1	0.6	0.2	0.6	0	1.4	0
Lower body region								
4	Thighs	1.1–2.4	1.7	1.5	2.1	0.8	2.8	1.9
5	Knees	0.6–2.2	1.7	1.3	1.5	0.5	2.5	1.5
6	Foot	0.6–1.7	1.0	0.9	1.0	0.4	2.2	1.0

rigid frame-geared bicycle showed the very least score (~0.2), below the minimum limiting range (=0.4).

On analysing the upper body region, the region of the chest is also considered. *Pectoral muscles* in the chest region are actively utilized in cycling activity. From Table 2 it is found that again single suspension bicycle users reportedly showed a significantly ($p < 0.05$) high pain score (~1.4) from the maximum limiting range (~1.1). Gearless bicycle showed a significantly ($p < 0.05$) very less pain score (~0.2) than the minimum limiting range (~0.3). Geared and mountain bicycles showed an optimal average pain score (~0.6). Surprisingly, no effects over the rigid frame-geared bicycle and single suspension-geared bicycle were observed. They have the value of "zero" on the pain score scale. Since the abdomen metric range did not show a significant response, it was neglected for further analysis. During cycling, one of the main muscles at work is the ones in the thighs viz., *Quadriceps and hamstrings.* Hence cycling seems to cause notable effects, problems, and pain in the lower body [4]. It is also said that at times people undergoing strenuous exercise (here, in this case, cycling) can get *Meralgia paresthetica* [7]. A huge amount of pain was also observed in the thigh region which varied with the cycle type used by the participants (Table 2). Significantly ($p < 0.05$) high pain in the thigh region by riding with a single suspension bicycle (~2.8) when compared with other designs such as Mountain bike (~2.1) and the combo of single suspension and geared cycle (~1.9). A significantly ($p < 0.05$) low pain is observed in people using a combo of a rigid frame and geared cycle (~0.8). Many cyclists have reported knee functional disorders as lower extremity non-traumatic injuries [8]. Knee injury is the second most reported overuse injury for cyclists [6]. Table 2 shows that the knee pain is present in almost all the type except for the rigid framed geared cycle which shows that its users have significantly ($p < 0.05$) low pain of approximately 0.5 as compared to other types, Single suspension cycle users seem to face the highest pain of 2.5 (approximately). Followed by, the other cycle types. Since no significant metric measures were observed in the buttock's region and calf muscles, the data corresponding to these two regions were neglected for further analysis. The energy transfer from the cyclist to the cycle is done through the foot region, which can be the reason for injuries and pain [14]. Foot pain is also said to be due to various other factors like the angle of the foot placed, the part of the foot used for peddling (the forefoot is the most affected), and the cycle variant used. Participants using a Single suspension cycle have a significantly ($p < 0.05$) high Pain score table with the value of ~2.2 as shown in Table 2. They have reported enduring more pain than the rest cycle design. Whereas the combination of (geared cycle and rigid frame) users have the least pain in the foot region (~0.4). The remaining mentioned type of cycle users tends to endure almost the same range of pain (~0.9 to ~1).

4 Conclusion

Based on various aspects and criteria, required details were collected from the participants and for a better perspective, the pain endured by the participants in different region of the body was obtained and their physiological effects were noted.

In support of our analytic results, previous research done by Priego Quesada [10] have used logistic regression analysis, and their findings highlighted that there are many factors associated with cycling-related injuries that led to discomfort and pain endorsement. They have also analysed and observed from various studies that the modification in the saddle resulted in high compression pain in the lower back and gluteal area which was often accompanied by skin discomfort, syndrome such as urinary pain, and numbness in the perennial region. They have also reported that high exposure to cycling on due course, has acclimated the cyclist to a higher pain threshold. So with the results obtained, it is clear that the type of cycle used plays a major role in the pain and discomfort from which we can suggest the designers to incorporate the possible rigid and geared designs in the single suspension design and others.

The main findings were based on the RBG pain score:

1. Difference in pain with Male and Females: It was noted while analysing from the graph that the female community felt more pain than the male in all the regions viz., hip and knee.
2. Upper Body region: Maximum pain was felt in the region of spine for the cyclists using single suspension cycle when compared to the hip and chest.
3. Lower Body region: The pain felt in the region of the thigh had the maximum RBG score and it was nearly the same in the knee.

Based on the cycle used: Analysis of spine, chest, and the hip region showed that the pain was endured to a maximum level when the cyclists used a single suspension cycle and minimum pain endured while using the combination of (geared and rigid framed cycle). The results were almost the same for the Lower Body region with respect to the type of cycle used. So in accordance with the results, we can suggest the users to go for the rigid and geared combination cycle rather than the other cycle as it is ergonomically better. This survey has given the idea of the physiological effects of cycling. The RBG pain score helped for better analysis on a different region of the body along with the variant of cycle used and the ergonomic design of cycling that plays a major role in MSD.

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Incidence of Forward Head and Rounded Shoulder Posture in Sports Involving Overhead Activities Among University Athletes

Sarika Chaudhary, Blessy Philip, Umesh Kumar Maurya, and Shweta Shenoy

Abstract A great deal of stresses are placed on the shoulder complex while performing overhead activities in sports that involve actions like throwing or hitting a ball because of repeated force generation, asymmetry in the loads or use of limbs. The development of postural defects like the forward head posture (FHP) and round shoulder posture (RSP) make the athletes more susceptible to shoulder injuries. To assess FHP, RSP and shoulder pain and disability index (SPADI) in players presenting with shoulder pain. 75 participants aged between 18 and 25 years, playing sports involving overhead activities and had a complaint of shoulder pain were included in this cross-sectional study. FHP and RSP was evaluated using photogrammetry method (autoCAD software). The shoulder pain and disability was assessed through a questionnaire (SPADI). The percentage of players presenting with FHP and RSP was 38.67% and 53.33% respectively. Mann-Whitney U test was applied on the SPADI score of the participants having FHP/RSP and not having FHP/RSP. Significant difference was only seen in the mean rank of total score of the players of "having FHP" and "not having FHP" whereas no significant difference was found in RSP group. It can be recommended that the players having FHP and RSP should undergo a posture correction program to prevent any kind of shoulder injury. The findings of present study can provide a guide to coaches and physiotherapists for better assessment of a painful shoulder which can also prevent recurrence of injury.

Keywords Forward head · Rounded shoulder · Posture · Shoulder pain · Overhead sports · Disability

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1 Introduction

While exercise is known to improve muscle balance, neuromuscular coordination, proprioception and hence posture [1], repeated activity or overuse of a muscle group especially when the overuse is unilateral can lead to a "Faulty posture" giving way to setbacks in other parts of the anatomical chain. A faulty posture places extra stress on the joints [2].

Exercise is known to improve posture but many researches have proved that regular training may have a crucial impact on a young individual's posture and physical development [3–9]. Further researches have proven the existence of a relationship between sports practice and shaping of the spine in sagittal plane, thus determining the posture of the athlete [5–7, 9–12]. Also, in contrast to the exercises that are symmetrical and recreational in nature, the overhead activities are usually unilateral; require more workload which may contribute to uneven strain on spine and other joints of the body, leading to postural defects [2].

The Forward head posture (FHP) develops because of faulty ergonomics and habitual adaptation to such faulty posture. It can be described as the anterior position of the head in relation to the theoretical plum line. The FHP can lead to change in the curvature of the cervical spine and the "uppercross syndrome" [13]. The uppercross syndrome is characterised by weakness of the deep cervical flexor muscles, rhomboids, serratus anterior and the lower trapezius which exists with tightness in muscles like pectoralis major and minor, upper trapezius and levator scapulae [13]. Because of the attachment of these muscles to the cervical spine and scapula, and the muscular imbalances, there is change in the scapular mechanics leading to increased stress on the shoulder leading to shoulder pain and dysfunction [14]. Along with their attachment to the scapula, these muscles also find attachment on the cervical spine and humerus. Round shoulder posture (RSP) develops in association with the FHP and causes the scapula to protract, elevate and rotate downwards [15–17], changing the alignment of the glenoid cavity and hence the humerus. The athletes with an incidence of posture deviations may be more susceptible to injuries [2] and hence it becomes crucial to consider the position of the cervical spine and scapula while dealing with shoulder pain.

Overhead throwing is an extremely skillful and complex movement and it places tremendous stress on the shoulder complex as enormous forces are generated [18]. In overhead athletes, the kinetic energy and force is generated in the lower limbs, pelvis and trunk and if funnelled through the joints of the shoulder girdle (glenohumeral joint, scapulothoracic, acromioclavicular and sternoclavicular joint) it eventually results in maximal distal upper extremity segmental velocity which is required for optimal overhead performance. Such stresses challenge the anatomical limits and physiological capacity of the shoulder joint and if there is incidence of faulty posture, these stresses are increased.

The average of injuries reported in the secondary school male and female volleyball players is 5%. The rate of injury in senior elite male handball players is 12% [19, 20] and 36% in the early preseason in senior elite female handball players [21].

In the game of Cricket, the incidence of shoulder injuries was reported to be 5.5% of all injuries amongst first-class country cricketers by the England and Wales Cricket Board and 5.2% was reported in South Africa and the same was reported to be 7% amongst the first-class Australian teams during the 2001 and 2002 seasons [22]. Swimming is an individual sport which involves propelling one's body forward in the water. It is done for exercise, recreation, and competitive purposes. 90% of force used to propel the body forward comes from the upper extremity [23]. Competitive swimmers practice 6–7 days a week and on an average they swim 1200 m each day [24]. Studies have shown that 47% of the collegiate swimmers experience shoulder pain persisting for more than 3 weeks, leading to a cessation or alteration in their normal training routines [25]. Among swimmers an incidence of 45–91% of interfering shoulder pain has been reported. A latest research reports the incidence of sports injuries occurring in the overhead sports bas being 58–69% in Baseball including the pitchers and the position players [26–29]. A 14–25% incidence in softball, including the pitchers and position players [30, 31]. Among the cricket bowlers the incidence is found to be 12.5–41% [32–34]. The incidence among handball and volleyball players is 7–14% [21, 35, 36] and 8–60% [37–40] respectively.

As we have gone through the literature, we observed that the shoulder pain has become a debilitating factor which affects the athletic performance. This pain is a result of development of faulty posture. Knowing the incidence of FHP and RSP may help in understanding the intrinsic factors leading to shoulder pain among overhead athletes. It may also aid in clinical decision making of assessing and correcting the FHP and RSP when an overhead athlete approaches with shoulder pain. The purpose of this study was to identify the incidence of FHP and RSP among overhead athletes with shoulder pain.

2 Methods

Study Design

Cross-sectional research design and sample size was calculated using power analysis (g*) and sample size (PASS) 2008 software.

Participants

75 university male athletes involved in overhead sports (Basketball, Volleyball, Handball, Cricket, Swimming, Discus throw) were included in the study. The athletes were selected on the basis of criteria; age between 18 and 25 years, involved in an overhead sport for minimum 3 years, had a complaint of shoulder pain, no history of injury or any surgery of shoulder and were not undergoing rehabilitation. The study was approved by institutional ethics committee (No. 32/HG dated 4/2/2019).

Procedures

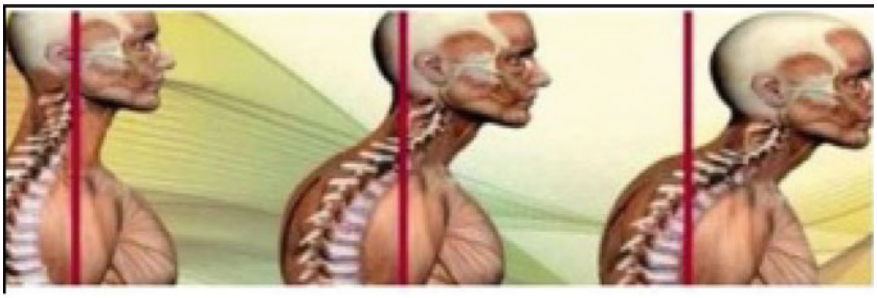
The data was collected between the months of August to December 2019. All participants read and signed the consent form before participating which was made available to them in English as well as regional language.

SPADI Score

The data was collected for the FHP and RSP using photogrammetry method. Three anatomical landmarks on the patient's body were marked including the tragus of the ear, the acromion tubercle and the spinous process of C7 vertebra. The participant stood 23 cm away from the wall and the photography tripod with the digital camera (Fujifilm FinePix S9600) was placed 265 cm away from the wall. The height of the camera was adjusted at the level of examinee's right shoulder. The participant was then asked to bend forward three times and raise the hand above the head three times and the stand normally and relaxed. The photo was taken after a pause of 5 s. Finally, the photograph was transferred into the computer and autoCAD 2018 software was used to measure the angles between the line joining the marked anatomical landmarks. To measure the forward head posture, the Forward head angle was measured, which is described as the angle of inclination of the line extending from C7 to the tragus and the vertical reference line. To measure the rounded shoulder posture, the Forward shoulder angle was measured which is defines as the angle of inclination of the line extending from C7 to the acromion and the vertical reference line. The athletes were categorised as having FHP if the forward head angle was more than 46° and the others were categorised as not having FHP [41]. The athletes having Forward shoulder angle more than 52° were categorised as having RSP and others were put in the category of not having RSP [42] (Fig. 1).

3 Results

The percentage of overhead activity athletes with shoulder pain and also presenting with FHP and RSP was calculated along with descriptive statistics for each variable. The participants in presenting with FHP and RSP were categorized as "having FHP/RSP" and others as "not having FHP/RSP". T test was applied to compare two categories of participants, "having FHP/RSP" and "not having FHP/RSP". Mann-Whitney U test was applied on the SPADI score of the participants having FHP and RSP. The SPADI scale has three variables; the Pain scale, Disability scale and total score. Significant difference was only seen in the mean rank of Total score of the symptomatic and asymptomatic group in Forward Head posture as the level of significance was less than 0.05. The statistical significance level α was set at .05 for all comparisons. The statistical analysis was done using SPSS version 23.0 (Table 1).



a. shows head weight of the person increases with every inch of forward head posture.

b. shows photogrammetry method of athlete.

Fig. 1 **a** Shows head weight of the person increases with every inch of forward head posture, **b** shows photogrammetry method of athlete

Table 1 Demographic data of the all participants including age, weight, and height

Variables	Mean	Standard deviation
Age	20.21	2.055
Weight (kg)	67.71	9.494
Height (cm)	167.40	7.102

4 Discussion

Overhead athletes are weighed down by the burden of shoulder pain and dysfunction, leading to deterioration in their performance, prolonged period of rest to recover from the injury and undergo rehabilitation or a shortened career in the sport.

Shoulder pain is a result of some extrinsic and intrinsic factors. The extrinsic factors are repetitive overhead use (>60° of shoulder elevation), sustained overhead work, and higher loads raised above shoulder height [43]. The intrinsic factors include Forward head and rounded shoulder posture [44], altered scapular mechanics and muscle activity [45]. Thus in sports involving overhead activities, it becomes vital to study the intrinsic factors that cause shoulder pain as there is no escape

Table 2 Symptomatic and asymptomatic distribution of forward head posture (FHP) and rounded shoulder posture (RSP)

Variables	Opts	No. of players	Percentage	Mean	Std. deviation
FHP	Symptomatic	29	38.67	47.86	0.79
	Asymptomatic	46	61.33	39.19	4.71
RSP	Symptomatic	40	53.33	59.30	4.93
	Asymptomatic	35	46.67	45.60	5.34

from the extrinsic factors as it is important for the players to train for certain hours a week. It is important to study the shoulder pain in various overhead sports as it prevents the player from routine practice, lowers self-confidence, compromises optimal performance.

The present study made an effort to find the incidence of intrinsic factors that may contribute to the shoulder pain. These intrinsic factors under the study were forward head posture (FHP) and rounded shoulder posture (RSP). The results showed that among the 75 overhead athletes with shoulder pain, the incidence of FHP and RSP was 38.67% and 53.33% respectively (Table 2). A previous research conducted on collegiate swimmers measured shoulder pain and function, before and after taking posture correction exercises for the FHP and RSP over 8 weeks. The shoulder function was not statistically different following the intervention, yet demonstrated a trend towards decrease in the shoulder pain and dysfunction. This trend suggested that there could be a relationship between the correction of FHP, RSP and shoulder pain [46]. Another research reported FHP was significantly greater in subjects with overuse shoulder injuries than in healthy subjects [47]. Similar study of 70 male volleyball players between the age of 18–34 years showed the prevalence of both FHP and RSP in them [48, 49]. However there are researches that have not shown a clear relationship between the presence of FHP and RSP in individuals with shoulder pain [50, 51].

A research which compared scapular kinematics and muscle activity in individuals free from shoulder pain, with and without FHP and RSP, the results of this study provided support for the clinical hypothesis that FHP and RSP impacts shoulder mechanics independent of shoulder pain [52]. There was a study which assessed and compared the cervical posture of collegiate students with collegiate basketball players (15 subjects in each group) by measuring the forward head angle and forward shoulder angles using photogrammetric method. Both the groups did not show any significant differences for any of the two angles. Hence it was concluded that posture of cervical spine of collegiate students does not have any significant impact of playing basketball [53].

In the present study, the maximum value of SPADI was 58.5 in athletes "not having" and 63.9 in athletes "having" FHP and RSP respectively (Table 3), which shows that there is a relationship FHP, RSP and shoulder disability. Significant difference was only seen in the mean rank of total score of the symptomatic and asymptomatic group in only participants with FHP. Significant difference was only seen

Table 3 SPADI score of forward head posture and rounded shoulder posture

Variables	Forward head posture		Rounded shoulder posture	
	Asymptomatic	Symptomatic	Asymptomatic	Symptomatic
Minimum	20.8	32.25	20.8	27.9
Maximum	58.5	63.9	58.5	63.9
Mean	39.87	45.34	39.88	43.84
Std. deviation	10.37	9.03	10.35	9.77

Table 4 Mean values of SPADI dimensions among symptomatic and asymptomatic groups of forward head posture and rounded shoulder posture

Variables	Forward head posture		Rounded shoulder posture	
	Asymptomatic	Symptomatic	Asymptomatic	Symptomatic
Pain scale	31.83	34.97	31.74	34.21
Disability scale	19.54	22.79	19.53	21.92
Total score	39.87	45.34	39.88	43.84

Table 5 Mann-Whitney U test between the pain scale, disability scale and total score of the forward head posture and rounded shoulder posture in symptomatic and asymptomatic players

Statistical test	Forward head posture			Rounded shoulder posture		
	Pain scale	Disability scale	Total score	Pain scale	Disability scale	Total score
Mann-Whitney U	545.00	454.50	463.00	589.50	529.00	565.50
Asymp. sig. (2-tailed)	0.186	0.007	0.022	0.289	0.045	0.093

in the mean rank of total score of the symptomatic and asymptomatic group in FHP whereas in RSP the SPADI score showed no significant differences (Tables 4 and 5).

5 Conclusion

The present study was designed to solve the problem whether the overhead athletes are more prone to altered neck and shoulder posture and whether the athletes having altered shoulder posture were more prone to shoulder pain and dysfunction. After analyzing the data, it can be concluded that incidence of FHP (38.67%) and RSP (53.33%) was observed. Whereas significant difference was only seen in total score of SPADI in FHP. So posture correction of these athletes may prevent potential shoulder injuries as FHP and RSP have been identified as an intrinsic factor contributing to shoulder pain in the earlier researches. In the overhead athletes with shoulder pain, it can be recommended to the 38.67% having FHP and the 53.33% having RSP to

undergo a posture correction program. The results of present study may also help to improve the assessment and protocols for the treatment of players who suffer from shoulder injuries and may play a major role in preventing recurrence of the injury.

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The Need of a Digital Typeface for Assamese Script

Bedanta Madhab Batchas and Mohammad Shahid

Abstract India is a land of vast diversity, a home to hundreds of communities and languages. In the northeast of India lies Assam. Even with the existence of multiple tribes and languages in Assam, Assamese is considered as the official language with more than 15 million speakers and serves as lingua franca of the region. Though there are differences in spoken medium, the script for Assamese language is very similar to that of Bengali script, historically there were certain differences in the former scripts but the ones which are being used now are the same except the character 'ৰ' (ra) and '৵' (wa), which is missing in Bengali script. However, there are not a lot of Assamese Unicode typefaces available on the internet. Even among the available ones most of them have been designed for print mediums like newspapers or magazines. This paper is aimed to understand different guidelines important for designing a digital typeface by reviewing existing literature and to design a new Assamese typeface suitable for screen based applications.

Keywords Indic typeface · Legibility · Type design · Assamese font

1 Introduction

India is a country with vast linguistic diversity consisting of around 454 different languages [1]. These languages belong to several language families, Indo-Aryan languages which has more than 78.05% speakers is the major one followed by Dravidian languages with 19.64% speakers [2, 3] and the rest belong to the Austroasiatic, Sino–Tibetan, Tai–Kadai and a few other minor language families and isolates [4]. Indo-Aryan languages are mostly spoken in Northern India which includes languages like Hindi, Bengali, Marathi, Urdu, Gujarati, Punjabi, Kashmiri, Rajasthani, Sindhi, Assamese (Asomiya), Maithili, Odia etc.

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Assamese or Asomiya is the official language of Assam, a state in Northeast India and serves as the lingua franca of the region. Assamese is spoken by 15,311,351 people in India which rounds up to 1.26% of total population [5]. Assamese follows 'Bengali-Assamese script' to depict the language in written form. According to Carmen Brandt the script is known variously as "Eastern Nagari script" in academic discourses; as "Bengali script" among Bengali speakers and as "Assamese script" among Assamese speakers [6]. Apart from these two languages, Chakma, Santali, Sanskrit, Sylheti and a few others are written in the same script [6, 7].

This script is an evolution of the 'Siddham' script which had its origin in 'Brahmi' [8]. Although both Bengali and Assamese scripts are visually identical, there are two major differences in their sets of characters, first one being the visual difference in the character ' ৰ' (ra) and the second being an extra character ' ৱ' (wa).

Lately, the researchers have been focusing their attention on the study of non-Latin scripts as a major part of the global population follows non-Latin including Indic scripts. These scripts are widely used in the field of education, media, advertising, design etc. and are mostly seen being used in newspapers, posters, magazines etc. The script in discussion that is the Bengali-Assamese script has the same usage on a daily basis. With changing day and time a major part of the print media is converting to digital and with the onset of digital revolution, concerns regarding various factors including typography are being introduced.

Eleven existing Assamese unicode typefaces were being looked into as a part of the study which are Nirmala UI, ASOT-Bidisha, Lohit Assamese, Arial Unicode MS, Nava Uni, Madhav Uni, Kirtan Uni, Bangla, SolaimanLipi, Vrinda and Rupali. This revealed that seven of these typefaces are of high stroke contrast and are mostly suitable for print medium [9–11] and the issues with the remaining four typefaces have been discussed on the later stage of this paper. This sets up a need in understanding the issues that concerns the legibility and readability of an Assamese typeface which is to be used for digital medium.

Therefore, this study focuses on understanding the issues related to existing typefaces and deriving guidelines important for designing a digital typeface by reviewing existing literature. These guidelines have subsequently been used to design a new Assamese typeface suitable for digital medium use.

2 Literature Review

2.1 Origin of Bengali-Assamese Script

The Bengali-Assamese Script has its origin in Brahmi. The script evolved throughout the years in various ways ultimately tracing its way to what it is today as shown in Fig. 1. The origin of this script dates back to around the tenth century CE [8].

Various factors like culture, economy, palaeography, technology, society and politics contributed to this evolution.

Fig. 1 Evolution of Bengali-Assamese script. *Source* [8]

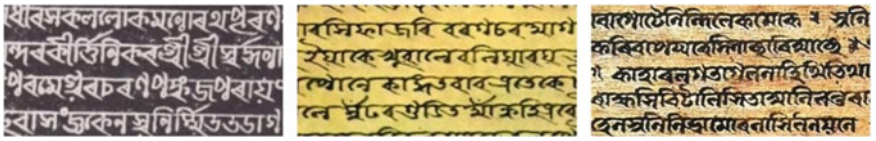

Fig. 2 Garhgaya style, Kaitheli style and Bamuniya style (from left to right). *Source* [12]

2.2 History of Assamese Script

Even though Bengali and Assamese scripts are named together and in the current scenario all the Assamese typefaces are derived from Bengali typefaces but according to historians there were certain visual differences in the writing style of this script. The historians looked into the Assamese scriptures inscribed in Rocks, Agarwood (Saanchi) tree bark manuscripts and coins, three major written styles were discovered dating back to different medieval time periods namely Garhgaya style, Bamuniya style and Kaitheli style of writing as shown in Fig. 2. Garhgaya style had sharply defined curves and angles of the letters and the writing style was simple and had very little to no ornamentation. This style of writing has higher legibility compared to the other two styles. The simplicity of the writing style plays a major role in easy perceivability of this style of ancient scripture. Kaitheli, on the other hand, was very highly ornamented and the letters to words followed a continuous long line without a break and in some cases these lines ended with a curl at the right end. The Bamuniya style was also ornamented with tendrils at the end of the letters and in this writing style conjuncted letters had a similar height to that of a single letter [12, 13].

2.3 Anatomy of Assamese Script

The Assamese script consists of eleven vowels and thirty seven consonants, the numbers and a few punctuations. Excluding the former, there are around five hundred conjuncts and a few ligatures in this script. This script can be called an Abugida which means every consonant in this writing system ends with the sound of a vowel. There are also additional symbols like ‘hasanta’ to mute the sound of the following vowel

and modifier signs Hasanta-ta, Anusvara, Visarga and Chandra-bindu which are used to denote different sounds. There is no uppercase or lowercase.

The anatomy of these letterforms is developed on the basis of three different aspects; structural grid lines, Anatomical Features and Anatomical parameters. In day to day practice the structural grid lines set the ratio of height and proportion of the letters [14]. The letters can also be categorized based on the anatomy into two sections, first one being categorization based on common character and the second one is categorization based on common structure [14, 15]. For the first, categorization is done based on most common anatomical features that exist in the script which are the Vertical Stem, the Bowl and the Leg. And for the second, the letters are grouped based on the common strokes and features [9, 14, 15].

Structural Grid Lines: A six line virtual grid structure is defined which helps in setting up the vertical proportions of the letterform. These six lines as shown in Fig. 3 starts from the Topmost Line or the Ascender Line, followed by the Shiro-rekha or the Headline, Initial Line which is also known as the Shoulder Line or the Upper Mean Line, Lower Mean Line, Lower Kana Line also known as the Footline or the Baseline and ends on Extreme Bottom Line or the Descender Line [9, 14].

Anatomical Features: There are seventeen distinct features in Bengali-Assamese typeface as stated by Chandra [14] which are Arm, Lobe, Bowl, Bud, Knot, Stem, Half Stem, Shoot, Delta, Tail, Wedge, Loop, Nose, Dot, Terminal, Aperture and Leg [14]. Figure 4 shows the features of letters ‘ অ’ (a), ‘ ক’ (ka) and ‘ উ’ (harsha-u) as these three letters consist of most of the above-mentioned features.

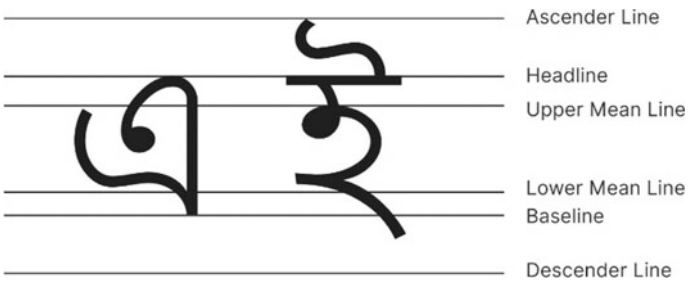

Fig. 3 Grid structure of Bengali-Assamese script using Lohit Assamese font

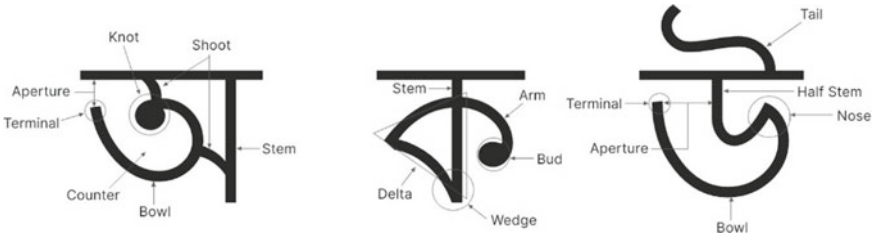

Fig. 4 Features of ‘ অ’ (a), ‘ ক’ (ka) and ‘ উ’ (harsha-u) using Lohit Assamese font

Anatomical parameters: Stroke thickness and stress on the stroke path are two anatomical parameters that are being observed in these letterforms. These characteristics are translated from its calligraphic styles to the typographic characters. There are fonts with varying thickness through every letterform and there are fonts which have a uniform thickness. The stroke thickness plays a significant role in the legibility of the font [14].

2.4 Legibility in Assamese Script

Legibility in typography and type design has various definitions according to researchers. Summarizing all those definitions says that legibility is the perception of the letters that deals with the explicable form and distinctive letter-shape which can be measured by two factors, visibility and familiarity [9, 16]. Visibility stands for recognizability of a single character and familiarity is the ability to distinct one letter from others in the group. Legibility is very much dependent on the anatomical features of the letters and a few other factors like Gridlines, Stroke Width and Weight, Stroke Path and Treatment, Stroke Density, Terminals, Optical Size, Stroke Contrast, Proportion, Structure, and Counter [9].

Issues Affecting legibility in Assamese Script: There are a few issues that affect this Bengali-Assamese script which are stated below:

- Crowding in Indic scripts: Due to unique features like conjuncts and matras there arises another issue known as crowding or contour interaction. Crowding is a phenomenon when two or more outlines (of strokes) touch each other [9, 16] this as shown in Fig. 5. The viewer finds it difficult to identify the characters due to this interaction and hence it lowers the recognizability of the letters [16].

Fig. 5 Crowding in Bengali-Assamese script. *Source* [9]

- Complexity in letterform: Indic letters have a relatively complex form compared to Latin. If this factor is not considered while designing a typeface, it might lead to unwanted deformities in the letters. Also due to this complex form, extra attention needs to be given while designing heavier weights as it might reduce the gaps in the letters resulting in low readability [17].

Legibility based on Stroke specification:

- The stroke path is the basic identifying characteristic of the letters, whereas treatment is the design specification for the letter stroke; both together enable the readers to identify the letters and the family that letter belongs to [9].
- The ratio of the thinnest stroke to the thickest in a letterform is called stroke contrast. Typefaces can be designed with very high contrast to mono-linear (strokes with uniform thickness). The typefaces with high contrast are generally used for print media and mono-linear typefaces are designed in the modern period targeting digital usage [9–11]. This is shown in Fig. 6.
- The stroke density is much higher in the Indic scripts compared to Latin scripts. It gets even more in the case of the conjuncts [9]. The lesser the density the better the legibility.
- An optimal stroke width had to be kept in mind while designing the font family so that it does not create any distortion to the characters.

Legibility based on Anatomical features:

- According to Fiset et al. [18], terminals are the most important feature for letter recognition. However, his research is based on Latin script which only has a few terminals whereas in most Indic scripts, there are multiple terminals that end in various directions. Hence careful attention is required to design these letter parts [16]. The terminals of ' অ' (a) in Vrinda and Solaimanlipi fonts are shown in Fig. 7.

- The blob feature of Assamese letterforms can be designed in three main ways: knots, buds and no knot which results in a lobe formation. The design of this feature should be taken into consideration for better legibility of the letterform. Visually the one with just the lobe is cleaner but it lacks the traditional blob feature of the letters, the one with the knot and shoot adds more to the complexity of the letterform hence the letters with bud naturally tend to be the better practice while designing a letterform. This feature is shown in Fig. 8.

Fig. 6 Stroke contrast in Bengali-Assamese script

Fig. 7 Terminals of letter ' অ' (a) in different typefaces

Fig. 8 Blob features of letter ' অ' (a) in different typefaces

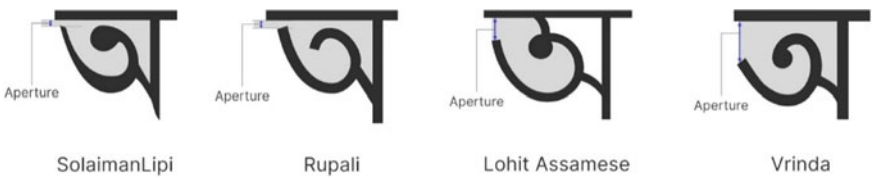

Fig. 9 Aperture of letter ' অ' (a) in different typefaces

- The width of the aperture of the letters can also affect the legibility of the letters. A study among few fonts with different aperture width is being conducted and it is found that the one with wider aperture tends to have better legibility in smaller as well as larger font sizes. This is shown in Fig. 9.

Through the literature review of various sources few main observations can be summarized pertaining to the origin, history, anatomy and legibility of the Assamese script. The evolution of Assamese language and script can be traced back to the Brahmi system in 100 BC. During medieval period the language saw three distinct writing styles out of which *Garhgaya* style of writing was observed to have better legibility compared to the others. The Assamese script was further studied to outline the anatomical features which helped in understanding the legibility factors related to the script. These understandings were incorporated to formulate design guidelines for a typeface suitable for digital medium, in the upcoming sections.

3 Methodology

Based on the literature review, following guidelines were derived for the reference while designing the new font.

- Mono-linear stroke contrast.
- Lesser stroke density.
- Wider aperture.
- Consideration to avoid crowding effect.
- Three weights for better use.

Eleven typefaces were looked into and the mono-linear typefaces among them have been selected to conduct a comparative study. The study was focused on various features that existed in these typefaces. Typefaces that were a part of this study are Lohit Assamese, Nava Uni, Rupali and Vrinda, shown in Fig. 10 and the observed characteristics are listed in Table 1. This study was conducted to determine the issues in the existing typefaces which later helped in designing a better typeface by improving on the existing issues.

Fig. 10 Assamese fonts available for digital usage

Table 1 Comparison between selected typefaces

Typefaces	Stroke density	Aperture	Stroke contrast	Available weight	Knots
NavaUni	High	Almost closed	Mono-linear with high contrast knot	Regular	Filled
Vrinda	Low	Open	Mono-linear with low contrast bud	Regular and bold	Hollow
Lohit Assamese	Low	Slightly open	Mono-linear with high contrast knot	Regular	Filled
Rupali	High	Almost closed	Mono-linear	Regular	Open

It was observed that NavaUni has very closed terminals, which when viewed in smaller size impacted its legibility and even though the font is mono-linear, the high contrast knots were too heavy for the font. Vrinda is the best one from this lot in terms of legibility but it complicates some features of the letters and the dots are placed at a distance from some letters, which impacts the recognition of the characters. Also, Vrinda is the only font which is available in both bold and regular weights; however, the font size differs a lot in both the weights (refer Fig. 11). Lohit Assamese has filled knots which affects the stroke contrast of the typeface and the kerning of the matra and the letters are uneven. Rupali removes the bud and the knot completely which removes one of the inherent features of the Assamese script. Similar to Vrinda, the dots are misplaced which affects the letter recognition. These issues are observed in certain softwares and might behave differently for others.

The analysis above was referred to while creating the font. The six-line grid system from Fig. 3 was used throughout and the terminals were ended at an angle of thirty degrees to the horizontal grid. As the first step, different iterations were made which included letterforms with and without the bud. In the end, it was decided to keep the designs with a small bud and a hollow knot as it was having the traditional features which make the letters more recognizable; Fig. 12 shows some features of the typeface.

Later corrections were made to certain characters and the final letterforms were decided as shown in Fig. 13. This font is just a concept, and the guidelines can be followed while developing a font for Bengali-Assamese Script. Although currently this typeface is designed in the weights of regular, bold and their respective italics,

Fig. 11 Size difference between similar font size regular and bold Vrinda font

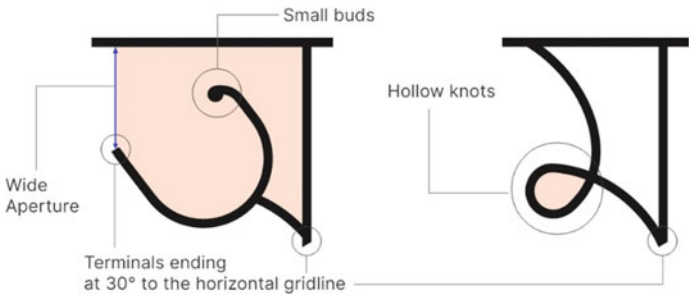

Fig. 12 Features of the designed font

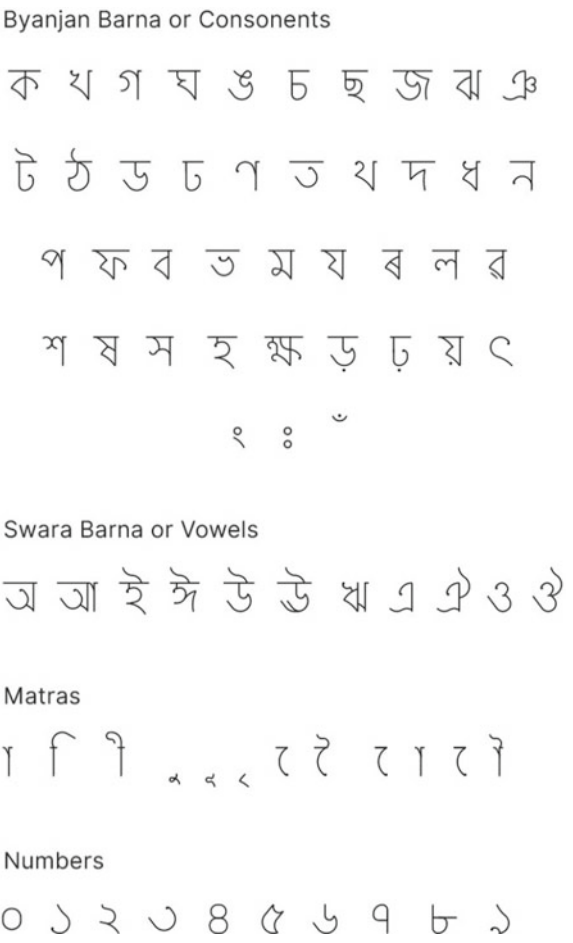

Fig. 13 Final letterforms in regular font weight

with time it more weights and even italics can be added to these letterforms. Few weights and italics of the typeface are shown in Fig. 14.

The issue of crowding is still persistent in case of some rarely used conjuncts as designing those within the gridlines were distorting the letterforms original structure or the size was not going with the defined proportion of the other characters. As of now this can be solved by increasing the default leading of the font but there is always scope for further research of this issue.

Fig. 14 Weights and italics of the typeface

4 Conclusion

This study looked into a few popular Assamese typefaces and found that most of them were designed for the print medium and very few were available for the digital medium. Even the available font which could be used in the digital medium had certain issues like uneven kerning, misplaced dots, different sizing among different font weights, smaller aperture etc. By reviewing various literature, different factors that affect the legibility of an Assamese script in the digital medium were identified. Although the factors that affect the legibility is same for both Latin and Non-Latin scripts, there are some other things to consider in the case of Bengali-Assamese script such as stroke weight in the buds and knots, whether to design the font with or without the bud, uniformity among multiple terminals that end in various directions etc.

The review concluded that, for the letters to have better legibility the typeface should have mono-linear stroke contrast, lesser stroke density, wider aperture, less to no crowding and should have a smaller bud rather than a knot with shoot or a lobe (no bud or knot).

By following these guidelines, a concept typeface with two weights regular and bold with their respective italics were designed. The study opens up further scope in terms of adding more weights to the typeface. The typeface is yet to be tested for its readability and legibility on digital medium however its attributes have been derived from the existing papers which talks about better legibility and readability.

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Incidences of MSDs Prevalent Among Indigenous Women Involved in Petty Trading in Assam

Bijoylaxmi Bhuyan and Nandita Bhattacharyya

Abstract Petty trading is a women dominated occupation of some indigenous people for income supplementation of family by selling home grown and naturally grown organic vegetables, herbs, rice, pulses etc. They sit daily to sell their products in market place for more than six hours/day round the year assuming continuous awkward posture. It is an important ergonomic aspect to focus at to understand the prevalent risk factors faced by women in this occupation. Majority of them complained of pain in both lower and upper back and was ranked I and II respectively, knees, neck and ankles were in IIIrd, IVth and Vth ranks. Some complained of numbness in lower limbs, frozen shoulders and many more. Positive correlation was found between age and level of musculoskeletal disorders among the respondents. Performance of different activities like carrying goods with head and back support in bamboo baskets, sitting in very low height or in squatting posture continuously with upper limb movement for lifting and reaching products was analysed through OWAS that revealed high value action categories which were indicative of "work postures with distinctly/extremely harmful effect on musculoskeletal system requiring immediate solution in working methods. The flexi scale measurement revealed a deviation of posture in upper and lower back from the normal walking and sitting.

Keywords Indigenous women · Squatting posture · Musculoskeletal disorders · Risk factors · Awkward posture

1 Introduction

Assam has 33 Administrative Districts out of which Karbi Anglong is the largest one with prominent indigenous Karbi inhabitants, having 982 female against 1000 male according to 2015–16 census [1]. Among the Karbi people, women are the backbone of their family; they work hard towards self reliance and are reflected through their conduct observed amongst both rich and poor, literates and illiterates. Here focus is

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on the women, who, despite being poor, discriminated; less skilled, deprived even of primary education yet contribute immensely towards economic development of the society. In any local markets one can easily find how prominently these women earn money with this petty trading. Petty trading is a market activity for income generation which is undertaken by some women. These women sell their products for long hours round the year by sitting in awkward postures for prolonged periods on very low height wooden '*pirha*' or on ground in squatting posture with their knees totally bent or cross legged, some of whom with breast feeding babies, and some at ages above sixty. Their products ranged from home/naturally grown greens, vegetables, herbs, pickles, fresh/processed bamboo shoots, pulses, grains dry fish, silk worms, traditional crafts including woven cloths etc. Their back breaking hard work and confidence, urge to become economically more secured, empowered and strong desire for their own identity is a motivation for every woman. Their strive to meet their dreams of long term economic sustainability will happen if they remain healthy and efficient physically and mentally over the years. Inappropriate body postures related to workstations is the primary cause of Musculoskeletal Disorders (MSDs). It was asserted in various population based survey which showed positive association between Musculoskeletal Disorders (MSDs) and work factors like awkward postures, high physical exertion and vibration [2]. International Labour Organisation reported that the risk of developing musculoskeletal disorders from an activity depends on the frequency, duration and physical demands of the activity [3]. Adoption of poor and prolonged awkward posture by workers leads to pain and increased exertion and results in Musculoskeletal disorder and decreased productivity [4]. Awkward body postures like twisting, bending, reaching and gripping were found to be risk factors in causing WMSD was asserted among women workers in packing units of pharmaceutical industry [5]. Women working in sitting posture holding it for longer period complains of physical discomfort like pain and numbness, in this connection, this study was undertaken to focus at the risk factors faced by the women associated with petty trading that involved carrying head loads in baskets, collecting sellable products and long hours of sitting uncomfortably.

2 Methodology

The study was undertaken with 50 respondents who were actively involved in this activity for more than three years from Diphu Market place (head quarter of Karbi Anglong, the hill district of Assam). A questionnaire was implemented to illicit background information regarding their involvement in the trade and analysed in terms of frequency and percentage. Nordic Body Map (NBM) divided body into 0–27 parts covering neck to feet and discomfort level was assessed using five point scale of Corlett and Bishop (1976) [6]. The modified Nordic questionnaire (C) was applied in the present study to understand Body Parts Discomfort of the women respondent. It represents different body parts starting from neck to feet. A five point rating scale of Corlett and Bishop (1976) was used with scores as given here with

(No discomfort = 1), (Just Noticeable discomfort = 2), (Noticeable discomfort = 3), (Tolerable discomfort = 4), (Intolerable discomfort = 5). On the other hand impact of age on levels of musculoskeletal discomfort was examined through a correlation test to understand if there was any impact of age on discomfort level of the respondents. Identification of level of risk factors due to the posture adopted for prolonged period during the activity of petty trading was done by Ovako Work Posture Analysis system (OWAS). It is a simple method to verify safety levels of work posture and to evaluate risk levels which helps to undertake corrective action. It was opined that OWAS method can define the movement of all parts of the body and can recommend suggestions for safer and comforter feeling while working [7]. OWAS method is more suitable to examine manual material handling it consisted of making observations of the work, codifying the postures, identifying risk categories and proposing corrective actions. Posture analysis was done with the help of flexi scale and then evaluation was done. It was used to measure the angle of deviation of spinal curvature in normal sitting in the usual upright posture of the women and in maximum deviated posture while sitting in doing the activity. The flexi curve was moulded to the contour of the spine and immediately drawn on a plain paper to measure the angle of deviation after that the average values of normal curve and angle of deviations were calculated. Thus, after collection of data, raw data were categorized and coded, analysed statistically, tabulated and represented graphically for inferences.

3 Findings

3.1 Demography

This section includes information on demographic background of the respondents; therefore, some of the relevant socio economic aspects like age, education qualification, main occupation etc. had been investigated and represented graphically (Fig. 1) to depict a minimum milieu of the respondents. Data showed that most of the women involved in petty trading were elderly and notably 20% of them were above 66 years (Fig. 1a). It was revealed that elderly women were not much involved in cooking and child care activities at home so they came out for earning through this practice. Considerable numbers (36%) of these women were widows while sixty four percent were married and had spouse (Fig. 1b). With regard to educational status majority (58%) were uneducated and 42% had been to primary school (Fig. 1c). Interestingly everyone knows counting of money very well and did dealings in the trade by themselves. Main occupation of the households was farming, followed by petty trading (Fig. 1d). However many of these women were involved in this trade as a secondary income generating activity. Most of the families of the petty traders were nuclear and had 5–8 members (Fig. 1e). Regarding monthly income (Fig. 1f) majority i.e. 84%

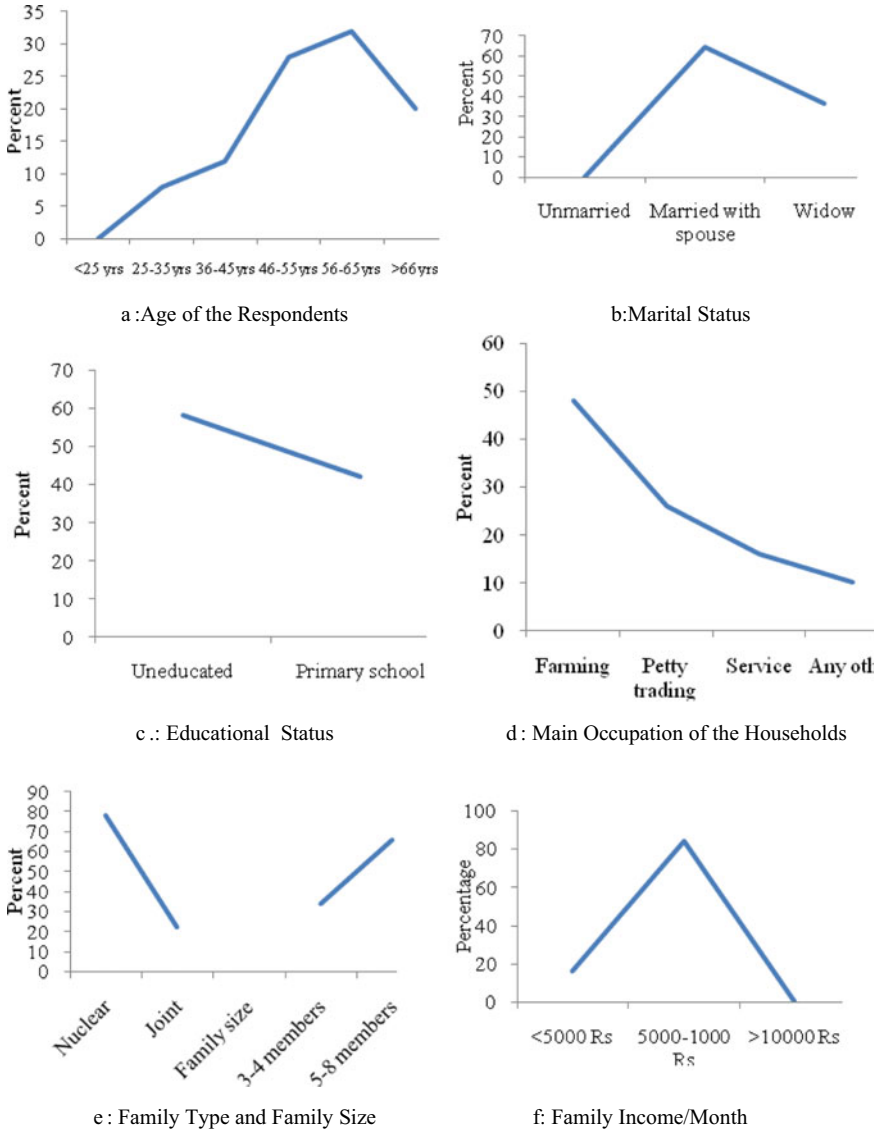

Fig. 1 Demographic characteristics of the respondents N = 50

of the families were having a earning of Rs. 5000–10,000. In this regard, it can be said that the women's contribution to the family income was significant.

3.2 Activity Description

During this activity of peddy trading, women collect the products from their home yard, farmyard and jungles and carry to the market. Some of these women come walking from their villages which were about 5–6 km from the market area carrying the load in bamboo basket hanged from head with the support of upper back and shoulder. Some come by Auto rickshaws with their products that charged them around Rs. 100/person. They sit in the market place for more than 6 h to sell their products. One of the commonest positions assumed while sitting for selling items was cross legged apart from squatting with or without support. They had to give Rs. 10/day to the town committee as a daily tax. One very interesting aspect about their money management practice was a regular per day savings pattern which was collected in the evening by an agent from Union Cooperative Bank. The rate of interest paid to them was Rs. 1000/10,000 annually.

This asserted that the women were economically secured; they contributed to the household expenditures and savings in a considerable way as reported they earned to support their families, wanted their children to be better educated and have better life. These women used to suffer from some ailments. Their common ailments were malarial fever, back aches, body aches, common cold, stomach aches and stomach problems (Fig. 2) apart from few with diabetes and hypo/hypertension. Some other prominent problems encountered by women of these hilly areas were insect bites and sometimes snake bites, Skin irritation was also very common problem among the women as they come into contact with dried leaves, barks, pollens and allergens while picking fruits and vegetables and such other activities in the jungle and in fields as they do not use any protective clothing or accessories.

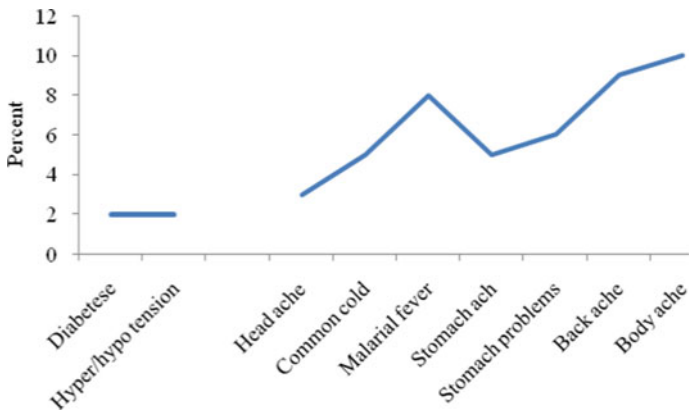

Fig. 2 Common ailments of the respondents

3.3 Estimation of Body Parts Discomfort Among the Respondents

Data in Table 1 reveals that tolerable discomforts were reported by respondents in lower back (56%), knees (50%), right shoulder (44%), upper back as well as ankles and feet (42%), left shoulder (40%), neck region (36%), buttocks (34%). While it was revealed that intolerable discomforts were perceived by 12% subjects in neck, right shoulder and knees, 14% in upper back, 10% each in lower back and ankles/feet. Many of the respondents indicated noticeable discomforts in hips/thighs, buttocks, shoulders, upper back, lower backs, ankles and feet. These discomforts may be due to awkward sitting posture with knees completely bent with or without seat and in squatting posture, bending and over reaching. The study conforms to the observation that stooping and squatting postures are common in developing countries like India [8]. The body discomforts were prominent in the study because the subjects were in a prolonged sitting posture most often without any seat/cushion on the ground or a low height seat without backrest and maintained their position for more than 6 h a

Table 1 Percentage distribution of body parts discomfort among the respondents (n = 50)

Sl. No.	Body parts	No discomfort (1)[a]		Just noticeable discomfort (2)[a]		Noticeable discomfort (3)[a]		Tolerable discomfort (4)[a]		Intolerable discomfort (5)[a]	
		F	%	F	%	F	%	F	%	F	%
1	Neck	12	24	9	18	6	12	18	36	5	10
2	Right shoulder	7	14	4	8	11	22	22	44	6	12
3	Left shoulder	8	16	6	12	12	24	20	40	4	8
4	Upper back	6	12	3	6	13	26	21	42	7	14
5	Right elbow	20	40	16	32	8	16	6	12	–	–
6	Left elbow	22	44	14	28	8	16	6	12	–	–
7	Right wrist/hands	21	42	18	36	9	18	2	4	–	–
8	Left wrist/hands	26	52	11	22	7	14	6	12	–	–
9	Lower backs	2	4	2	4	12	24	28	56	6	12
10	Buttocks	10	20	6	12	14	28	17	34	3	6
11	Hips/thighs	16	32	6	12	15	30	8	16	5	10
12	Knees	5	10	6	12	8	16	25	50	6	12
13	Ankles/feet	5	10	8	16	11	22	21	42	5	10

[a] Scores

day. It was reported that sitting posture has a disadvantage as it affects digestion and breathing due to prolonged slacking of the abdominal muscles and the purported ill effect of flexion on the spinal column [9]. Also in another postural study conducted on spinning operators, it was found that their health were highly affected due to improper body postures and workload [10].

3.4 Ranking of Body Parts Discomfort Perceived by the Respondents

The ranking of the discomfort in body parts was done on the basis of Body Parts Discomfort faced by the respondents. It was asserted by the ranking analysis that majority of the subjects had shown back pain in both lower and upper back and was ranked I and II respectively, knees, neck and ankles were in IIIrd, IVth and Vth ranks may be due to the prolonged awkward postures adopted by the women. Shoulder pain was also prominent which could be due to excessive bending, and overreaching to grasp items, weighing and selling and repetitive actions (Table 2), which could be

Table 2 Ranking of body parts discomfort perceived by the respondents (n = 50)

Sl. No.	Body parts	No discomfort (1)	Just noticeable discomfort (2)	Noticeable discomfort (3)	Tolerable discomfort (4)	Intolerable discomfort (5)	Total score	Mean	Rank
1	Neck	12	9	6	18	5	145	2.9	VI
2	Right shoulder	7	4	11	22	6	166	3.32	IV
3	Left shoulder	8	6	12	20	4	144	2.88	VII
4	Upper back	6	3	13	21	7	170	3.40	III
5	Right elbow	20	16	8	6	–	100	2.00	X
6	Left elbow	22	14	8	6	–	98	1.96	XI
7	Right wrist/hands	21	18	9	2	–	92	1.84	XIII
8	Left wrist/hands	26	11	7	6	–	93	1.86	XII
9	Lower backs	2	2	12	28	6	184	3.68	I
10	Buttocks	10	6	14	17	3	125	2.5	IX
11	Hips/thigh	16	6	15	8	5	132	2.64	VIII
12	Knees	5	6	8	25	6	171	3.42	II
13	Ankles/feet	5	8	11	21	5	163	3.26	V

the reason of complains of numbness in lower limbs, frozen shoulders, stiff neck, leg cramp, muscle cramp etc. In studies on repetitive nature of work that had resulted in shoulder and wrist pain was concluded that might lead to Cumulative Trauma Disorder (CTD) in the long run among the subjects [11, 12].

Rural women specially economically weaker section of tribal community undertake long hours of work requiring continuous attention, precision, holding themselves in extreme postures in doing variety of work that leads to serious physical stress. Studies asserted that age, strength and fitness are some of the factors which influence an individual's capacity and have a bearing on musculoskeletal problems [13, 14]. It was opined that these women also undergo physical stress combined with psychosocial stress that produces a level of musculoskeletal strain [14]. In another trade of fish processing, study on risk factors among women workers found that 71% women of 23 years of age worked for 6 years in this field and had reported MSDs, mainly in upper back (54%), lower back (33%), knee and shoulders (27%) [15]. Level of physical activity and work factors including sitting continuously for long period of time and working in confined space lead to low back pain. It was reported that 65.7% of the call center operators suffer from lower back pain and opined that the issue of MSDs is a major public health problem all over the developing countries [16]. Among women bamboo workers in Madurai, back pain was a major problem and holding poor posture for a longer time increased postural load and caused musculoskeletal disorder [17].

During computation of correlation (Table 3) it was revealed that there was a highly positive relationship between age and levels of MSD at different body parts and that with increasing age of the respondents' level of pain increased in neck, shoulders, upper back, ankles/feet, knees, right elbow, right wrist compared to lower back, left elbow and Hip/thigh.

3.5 Analysis of Posture Assumed by Respondents in Petty Trading

Position which holds the body upright against gravity is called posture. Strong muscles of the body act to support the body against gravity for maintenance of posture. These muscles get weak due to poor posture, which produces increased strain on the supporting structures which may cause changes in the posture and long term muscular-skeletal deformities. Observation of the activities of the women involved in petty trading revealed that (Table 4) they carry a load of more than 20 kg in bamboo basket with head, back and shoulder support, comes by walking and puts it down, spreads their polythene sheet by bending, spreads the products nicely over it to be visible for the buyers. They continuously sit on ground with bent knees, intermittently lift both hands and extend to reach the items, weighs them sometimes, put in begs and hands over to the buyer then they extend their hands to reach the money from the buyer, gives back the change if required and rearrange the items

Table 3 Relationship between age and levels of pain at different body parts of the respondents

'r' value	Neck	Right Shoulder	Left shoulder	Uperback	Lowebacks	Right elbow	Left elbow	Right wrist	Left wrist	Hips/thighs	knees	Ankles/feet
Age	0.862	0.765	0.760	0.787	0.578	0.626	0.560	0.621	0.543	0.355	0.673	0.730

Table 4 Analysis of the activities of petty trading on the basis of OWAS

Sl. No.	Description of the activities	Code	Score	Action category
1	Carrying basket with head and back support and walking	2272	3	Work postures have a distinctly harmful effect on musculoskeletal system. The working methods involved should be changed as soon as possible
2	Lifting hands above shoulder to reach items to buyers by sitting on ground in low height seat/without seat and without back support	4241	4	Work postures with an extremely harmful effect on musculoskeletal system. Immediate solution should be found to change these postures
3	Stretching hands time to time to arrange the items by sitting on ground or stooping with high back bending	4141	4	Work postures with an extremely harmful effect on musculoskeletal system. Immediate solution should be found to change these postures

and does the same for the next buyer and this continues till all their items are sold. The activities which were carried out by the women very frequently were analysed through OWAS to assert the risk factors involved.

Thus the OWAS score analysis (Table 4) revealed a high OWAS action categories of '3' and '4' that describes that work postures with distinctly harmful effect on musculoskeletal system and working methods involved should be changed as soon as possible in one activity where as in two activities work postures with an extremely harmful effect on musculoskeletal system and immediate solution should be found to change these postures has been recommended. A study on manual workers using OWAS posture analysis and Nordic body map questionnaire revealed that 95% of workers complained of musculoskeletal disorder and indicated OWAS action category 4 that required immediate corrective measures for workers safety [18]. 75% of workers working in tobacco factory with mean age of 43 years and working since 12 years were studied using Nordic questionnaire and were found to have MSDs, with 55% having pain in lumber region, followed by knee (45%) and shoulder (37%). OWAS posture analysis revealed that most postures were critical or need intervention for modification [7]. While carrying load on head hanging basket, head bends forward and shows a deviation from normal standing posture as shown in the table (Table 5). The load as recommended in ILO report is that the permissible limits of lifting and carrying load for women in comfortable outdoor climatic condition ranges from 15 to 20 kg [19, 20].

In order to assess the postural stress on women while at work (in sitting), the angle of normal curve of the spine in normal sitting in crossed legs on floor was measured at lower back regions of the respondents which was found to be 195.41° (Table 5). The angle of deviation was calculated after measuring the spine at the same point of lower back while sitting at work which was found to be 203.20°. The findings thus revealed that the angle of deviation from normal sitting in lower back was found

Table 5 Assessment of postural deviation of respondents while carrying load and sitting during petty trading (n = 50)

Measures of angle in sitting	Upper back while carrying load in basket	Lower back while sitting
Angle in normal position and SD	194.96° ± 2.09	195.41° ± 1.73
Angle in working position and SD	202.80° ± 2.30	203.20° ± 2.05
Increase over base	7.84°	7.79°
Percent increase	4.02%	3.99%

to be 7.79° the percent increase was 3.99%, which was 202.80°, 7.84° and 4.02% respectively in upper back of the respondents in case carrying load. Thus the analysis revealed a deviation from normal posture which was almost continuously assumed throughout the activities.

4 Conclusion

Thus, from the observations and analysis of the result it can be concluded that the women involved in petty trading were working in awkward postures with the potential risks of MSDs primarily affecting lower and upper backs, shoulder, neck, knees, ankles and feet and assessed to have higher ranks. Strong positive correlation was found that asserted that with increasing age MSD's were also found to increase in most body parts. A considerable degree of postural band was also visible in carrying load in upper back and working in sitting at lower back compared with normal walking and sitting and percentage increase was found to be 4.02% and 3.99%. A high OWAS score of '3' and '4' that describes work postures with distinctly harmful effect on musculoskeletal system and working methods involved needed to be changed as soon as possible because of harmful and extremely harmful effects on musculoskeletal system. Women suffer from various problems related to health on account of doing work without understanding their body demand in strenuous postures for prolonged hours. Which is also true with the Karbi women who were involved in myriad of activities apart from their involvement in petty trading that includes activities like collecting, picking carrying in baskets full of materials on head, sitting for hours together for selling despite vagaries of weather conditions but their strong mind and will power, considerable earning to support their families financially, spending time with friends in the market place keeps them going. Awareness is needed to be developed among the women to have a better workstation with a seat of proper height and an arrangement for display of items. The town committee can make some provisions for these women with electric fans and proper arrangements to sell their products hygienically and comfortably. Apart from this proper shade with adequate lighting, open space with adequate ventilation will help them to do their activity in the

market place. This will help them to reduce exertion and effects on musculoskeletal system and thus lead a healthful life.

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Gauging Global Green Governance of the Millennium: The Roadway Towards Human Progression

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Abstract Amidst waves of rapid changing digitalized global hemisphere environmental conservation is the call of the hour. Today it is quite pertinent to reframe the environmental sustainability agenda merged with global life support system for meaningful human survival. The new millennium of green revolution gives a futuristic look and recognized as a universal parcel of environmental protection worldwide. In this paper the essential objective is to reinvent the prime domains and items in tune with effective environmental restoration and proposing a conceptual framework for building global green governance. The research work is qualitative in nature based on primary and secondary data. The primary was collected by detailed survey questionnaire and the secondary data was collected from various books, journals, reports, newspaper and relevant websites. The five broad domains identified are Innovative Green Practices, Building Effective Environmental Management Tools, Upholding Environmental Ethics, Climate Change Proponents and Global Climate Governance using literature review as essential basis. A conceptual global environmental framework has been formulated study which can be used as a standing tool considering the novelty of the study in similar research work. The relevance of environmental restoration amidst present turmoil is of utmost concern in the present day global habitat. The study upholds that the right to healthy environment is not only the right of the present generation but indeed the very root of human progression on earth.

Keywords Environment · Green · Global · Human · Governance

1 Introduction

The eventual splendid gift bestowed upon human beings by the Almighty God is the nature, the environment. The term environment etymologically denotes surrounding and is formed by two words i.e. 'envo' connoting 'encircle' and 'ment' meaning 'all round'. Environment is the nucleolus of climatic, cultural conditions creating a deep

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impact on human life. The life-line of all living beings is deeply embedded within the green strata of natural environment. The ancient Indian scriptures of Rig-Veda foretells that Universe consists of five basic elements earth, air, fire, water and space culminated in the name of '*Panchabhoota*'. Through ages the human civilization was witnessed continual struggle towards protecting the environment for restoring human wellness and wellbeing. The proponents of preserving the global habitat can be traced from the King James Version of the Holy Bible chapter 1 verses 1–29 which narrates "*In the beginning God created heaven and the earth. And the earth was without form and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters. And God said, Let there be…and there was….So God created man in His own image….male and female created He them. And God blessed them and God said unto them: Be fruitful and* ***multiply and replenish*** *the earth….And saw everything that he had made and behold it was very good*." Keeping in tune with the words of the Holy Bible it can be witnessed that in the past four decades there has been a growing consensus in managing global human development in the context of overall sustainability of our planet. The new millennium paradigms of global environment agenda face the core questions in safeguarding the ecosystem and the challenges of the present—era environmental transformation, depletion in biodiversity balance supplemented with the allied alarming to wellness of humankind. Today it is unanimously accepted that the environmental protection is the bell-tone of global environmental policy framework [4]. A concern for environment preservation, creating awareness about ecosystem, addressing agendas of environmentalism is the call of the hour. It can be witnessed that the roadway towards human progression is the holistic vision of twenty-first century millennium and the need to decipher proper ecological perspectives enabling every humans to lead a green centric sustainable life at all levels—social-organisational-global.

2 Objectives of the Study

The focal purpose of the current paper is to examine and reinvent the prime domains and items in tune with effective environmental restoration and proposing a conceptual framework for building global green governance for human livelihood and sustenance.

The specific objective of the study can be understood in terms of the following detailed objectives of this paper

- To define the domains in light of humanistic element
- To define the sub domains/items relating to each domain on the basis of literature review
- To propose a holistic environmental—human friendly conceptual model for building green governance integrating human element, technology and occupational well being.

3 Review of Literature

3.1 The Quest for Climatic Change Constituents: Panacea for Green Governance

At the juncture of environmental and development issues the notion of climate change is considered to be the focal arena in advocating 'Climate Change Management'. In the couple of years restoration of greenhouse impact has induced in the creation of multistate Climate Registry to establish as uniform protocol in tracking and acting aggressive role to control climate threatening emissions. Studies reveal that climate change is already underway and due assessment of adaptation strategies need to be developed with the potential to enormously impact human welfare. A brief overview of the promising Go-Green initiatives for enhancing climatic preservation programme is elucidated in the panaorama of Climatic regulation strategies viz. Transit-Oriented Development, Energy-Efficient Buildings, Sequestration, Adaptation, Resiliency, Green Buildings & Green Neighbourhoods. Regarding green development a national system linked with sustainable development strategies need to be formulated and an outline of the role of each level of government has to be set up to create standard baselines and monitoring system for successful climate change management practices for the society at large [14].

3.2 Building Green Governance Competencies: A Holistic Approach

On the threshold of the digitalized era there has been a paradigm shift in the system of environmental governance ranging from ensuring healthy air, clean water, stable climate, safe-drinking water, vital ecosystem and continuing biodiversity across global platform. Today environmental governance is facing challenges viz. complex turbulent issues of green house emissions, degradation in wetland values, effect of bio-cumulative toxins on fisheries, ever-increasing urbanisation, nonpoint sources of water and air pollution, diminishing impact on air quality due to poisonous emission from vehicles, ships, aircrafts, manufacturing houses, rapid growth in urban industrial assets, advent of nano-technologies and many more. Amidst fluctuating, unpredictable and complex environment, proper assessment of new environmental governance requires new societal arrangements with set of standards and rules to establish and redesign innovative environmental standards for the community at large. The driving force behind reoriented environmental behavior is induced by the forces of common law, legislative liability standards, local environmental regulation, customer demands, investment decisions, company reputation, educational campaign and government role in supporting and promulgating information to the public good and welfare. At this juncture the call for novel approach to environmental

governance is the call of the hour [13]. With establishment of plentiful innovative environmental governance houses beginning with last decade and on, a panorama of rejuvenated green governance drives, a new millennium environmental-extravaganza has truly paved way for most desired environmental outcomes, and the functioning of green governance bodies ranging from National Academy of Public Administration (NAPA), The Aspen Institute, USA, President Council on Sustainable Development (PCSD), USA, National Adaptation Programme of Action (NAPA), Think-Tank Outlook, all integrated for resolving a suitable and alternative path promoting harmonious relationship for the societal and environmental development at large. Over the past few decades environmental problem solving has emerged as one f the pertinent issues worldwide. The salient new approaches postulates a way towards building a system of governance that can leverage significantly more on resources to retain the environmental equilibrium include Chesapeake Bay in United States, Minnesota's Response to Impaired Waters in United States, Urban Ozone and Particulate Pollution, Clean Air Minnesota, Brownfields Rehabilitation in United States, Managing Nanotechnology Development.

3.3 Environmental Ethical Code for Green Governance

Environment is the life-blood of human survival. Amidst digitalized and industrialization waves, the present era is on the threshold of managing the human use of biosphere that yields optimum ecological sustainability for the future generations. The natural resources gifted by nature are on the path of degradation, exploitation and indiscriminate misutlisation due to mass acceleration in scientific and technological development. A study of World Conservation Strategy propagates international awareness and discourse on the relevance of global green sustainable development. It is quite pertinent and fact that unsustainable development and imbalance in environmental strata will lead to a collapse of the inter-related systems of this planet. At this juncture the moral consideration of humanistic approach towards nature is quite imperative as not only food is required for human survival but there is a dire need of varied proponents of natural habitat to maintain the quality of life. Moral values in broader aspect consider three core constructs viz. self conscience, ideology and judgments. The deep, intricate and responsible relationship with human beings and natural environment encompasses the philosophy behind environmental ethics. Environmental ethics can be connoted as a study of relation of human beings and nature and the role to be played in maintaining such relationship constituting humans which are the part of the society and all other living creatures of this planet [18]. The cry for survival for the fittest, the urge to save the earth and natural environment the necessity of ethical doctrines need to be followed at species, ecosystem and individual level is depicted in Table 1.

The propensity to protect and preserve nature depends on how do we think and act. The success and sustenance of mankind vests on efficiently we are able maintain

Table 1 Layers of environmental ethical characteristics

Levels of environmental ethical orientation	Attributes
Species level	Right of every species for existence
	Right for every species for utilization of resources
	Collaborative human effort for preservation of earth's species
Ecosystem level	Ecosystem is the heart of the species
	Protection of ecosystem is the life-line of species
	Human beings should protect nature and natural habitat
Individual level	Utmost care and sensitive behavior towards nature
	Awareness towards limiting population
	Promoting consensus for living clean, green and healthy world

the equilibrium between utilization of nature resources and deriving the benefits for us from the nature.

3.4 Spectrum of Innovative Green Practices: Prospects and Challenges

In the present scenario one of the rapidly emerging issues is to propagate the heightened awareness of the natural environment reflected through green innovative practices. Millennial organizations tend to rely on promoting and developing innovative green products with a mission to create a competitive edge aiming for continual growth and advancement. The propensity towards adopting green centric mechanism fosters way towards building green economy and enhances overall efficiency of resources, better productivity reduction of waste restricts harmful consequences to the green habitat. Studies reveal that green innovation in the form of product of process is quite imperative as it alleviate the environmental effects of an organization and cultivates in creating an environment friendly climate for the people live with livelihood worldwide. The twenty-first century business houses are facing cut-throat competition, high cost technology, crisis of fund and uncertain fluctuating waves culminating towards bringing a adverse impact on the enterprises which has propelled the status of the organisation to think out of the box to reinvent, redesign and adapt green innovation regime. Innovation has been rightly coined as "Industrial Religion

Table 2 Green innovative practices

Panorama of green practices
Usage of green innovative products
• Usage of energy efficient refrigerators, micro-wave oven, dishwashers
• Panchakki-water management with energy generated water mill
• Application of green innovative products with low carbon emission
Green measures preogramme
• Adding colours from the medicinal herbs
• Planting plants that use less water
• Helpful in landscaping with planting of native shrubs and trees
Recycling solar energy
• Installation of solar panels for energy generation for lightning purpose
• Usage of solar energy transmitting power mode for transports
• Economic usage of watering of plantation through solar medium
• Net energy metering allowing consumers to generate electricity anytime
Waste management techniques
• Agricultural by-products used to create bio-fuel to power cars
• Bio-ethanol-alcohol based bio-fuel used in automobile industry
• Gelatin from tannery waste yield high quality product
• Leather waste is used in making aircraft, body of bike
Recycling construction debris
• Iron scrap, waste sheets, pipes etc. can be used for other structures
• Footpath can be constructed with chipped tiles, kota stone, granite
• Fly-ash can be used in the construction to preserve top soil, curb dust

of the twenty-first century Millennium". Research focuses that "*The concept of green innovation centres around exploitation, production or assimilation of all activities including service, production process, management of product and different methods that are new to the organization that adopts and develops them*" 'Adopt Green' is the growing buzz word of today's contemporary business hemisphere Green innovation can be visualized in viz. green product innovation, green process innovation, green system innovation and eco-innovation visualized in Table 2.

The worldwide agenda in upholding 'green globe' vests in building competitive advantage around quality, speed, variety, safety, design, reliability and embedded in creating a positive relationship between green innovation-green performance-green environment.

The worldwide agenda in upholding 'green globe' vests in building competitive advantage around quality, speed, variety, safety, design, reliability and embedded in creating a positive relationship between green innovation-green performance-green environment.

3.5 Integrating Global Climate Governance and Human Well Being

One of the most talked about concern that encompasses the global hemisphere represents the regulatory approaches towards environmental governance. The current global environment scenario amidst turbulent, fluctuating, unpredictable waves has compelled to initiate new modes of regulation in order to confront environmental challenges despite negotiation impasse. Global environmental governance in the twenty-first century faces core questions regarding role of purely state-driven international approach in the environment regulation portfolio. Studies reveal that private networks comparatively play an increasingly prominent role in global environmental regulations. The prime concern of worldwide climate regime regulatory innovation is the emerging issue of pertaining gap between forest-related negation and certification. In response to this concern a hybrid public–private governance approach to reduced emissions from deforestation and degradation (REDD) has been proposed that can reduce carbon emission and promoting a broad array of ecological and socio-economic co-benefits that encourage climate change adaptation and human well being. The significance of tropical forests for this global hemisphere is immense as more than 350 million forest-dependent people existing worldwide providing the utmost critical regional and global services. Tropical forests being the most diverse ecosystems on earth and associated human race is severely facing the threats from climate change and adverse drivers of deforestation and such pertinent issue in not being addressed adequately by the supranational bodies in the global platform till date. There is a close inter-relationship between tropical forests, climate change and human well being and such linkage must be understood in the perspective of international climate change regime. At the outset tropical forest governance needs utmost priority in implementing global environmental law with the potentials of state-based supranational institutions, informal intergovernmental bodies, public–private regulatory bodies and private entities. The true fact underlying the tropical forest ecosystem rests on subsistence requirements of large section of forest dependent rural indigenous population—the life line of human sustenance [5]. The synergistic effect of deforestation, biodiversity loss and climate loss poses a profound threat on human

habitat and perhaps propensity of human survival of millions is likely to exacerbate in the coming days. Although a variety of mechanisms, multilateral efforts and approaches exists to combat forest degradation but the emergence of World Wide Awareness for Nature for preserving the ecological value of nature need to be inculcated in the minds of the people for a healthy environment-rich economy-progressive society oriented world for the coming era.

4 Research Approach

The study is descriptive. The study has been based on secondary literature survey. Extensive literature review was done by considering research papers, journals, articles and government reports. Based on the literature survey and understanding five broad domains Climate Change Constituents, Global Green Competencies, Environmental Ethical Regulations, Innovative Green Practices, Global Climate Governance for Human Wellbeing have been identified. The essential focus of the paper is to connect these elemental considerations to rationalize their criticality towards comprehending green governance across the globe. A proposed environmental- friendly conceptual model has been formulated for feedback and future scope of the study.

5 Findings of the Study

5.1 Findings I

The Broad five Domains identified in the study are

Domain I: Exploring Climate Change Constituents for Green Governance
Domain II: Upholding Global Green Competencies for Green Governance
Domain III: Advocating Environmental Ethical Regulations for Green Governance
Domain IV: Introducing Innovative Green Practices for Green Governance
Domain V: Recognizing Global Climate Governance for Human Wellbeing.

5.2 Findings II

See Table 3.

Table 3 Sub domains against each domain

Domain	Description of sub domain
Domain I Exploring climate change constituents for green governance	Ia. Impact of climate change management
	Ib. Initiating energy efficient buildings
	Ic. Encouraging green neighborhoods
	Id. Advocating green building
	Ie. Upholding transit oriented development
Domain II Upholding global green competencies for green governance	IIa. Role of green governance bodies
	IIb. Implementing think tank outlook
	IIc. Governing ecosystem
	IId. Building green governance system
	IIe. Comprehending a holistic environmental approach
Domain III Advocating environmental ethical regulations for green governance	IIIa. Outlining global environmental regulations
	IIIb. Reviewing the role of ethical environmental governance
	IIIc. Highlighting levels of ethical environmental orientation
	IIId. Understanding the essence of ecological balance
	IIIe. Creating moral values towards environment awareness
Domain IV Introducing innovative green practices for green governance	Iva. Upholding green innovative practices for budding green economy
	IVb. Usage of green innovative products
	IVc. Recycling solar energy
	IVd. Waste management techniques
	IVe. Recycling construction debris
Domain V Recognizing global climate governance for human wellbeing	Va. Formulating green integrated approach for human well being
	Vb. Reduced emissions from disforestation and degradation
	Vc. Understanding the essence of tropical forests
	Vd. Outlining the linkage between forest-climate-human
	Ve. Formulating global awareness for Nature for human survival

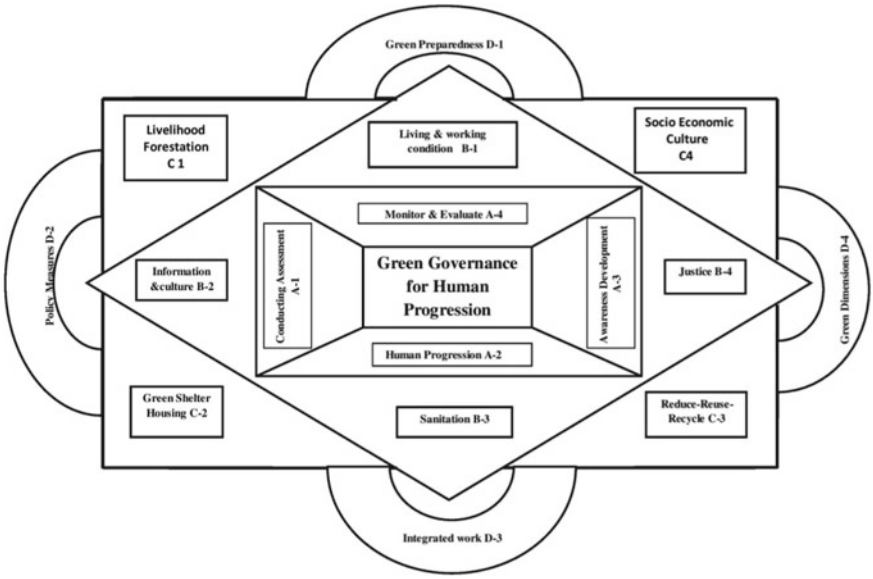

Fig. 1 Humanistic green governance model

5.3 Findings III

Model for Facilitating Holistic Environmental Governance for Human Progression

All the components of the model are explained in the following description, but these interventions are not sequenced according to the time phase rather these are integral functions that should be considered in reorienting environmental governance at different phases [10]. The proposed model is arranged in four levels and each level has four sub-functions depicted in Fig. 1.

Level-A: Cross Section factors Green Sustainable Interventions

A-1: Conducting assessment as an on-going process
A-2: Considering the human progression perspective
A-3: Encouraging Environment Awareness Development
A-4: Monitor and evaluate Environment Sustainability Programmes.

Level-B: Core Environmental function for psychological well being

B-1: Ensuring hygienic living and working condition
B-2: Facilitating environment information and culture for environmental knowledge
B-3: Introducing Environment sanitation programme
B-4: Monitoring environmental justice coordinating state-judiciary-people.

Level-C: Inter-sector Environmental awareness programmes facilitating human well being

C-1: Facilitating livelihood promotion and forestation programmes
C-2: Rebuilding green shelter/houses for the living population
C-3: Emphasizing Reduce-Reuse-Recycle approach for effective resource utilization
C-4: Facilitating in continuous implementation of green social-economic-cultural dimensions.

Level-D: Mainstreaming Green Governance for Holistic development

D-1: Organising Green preparedness initiatives
D-2: Introducing effective policy measure for green governance
D-3: Organising integrated work for environmental sustainability
D-4: Promoting multi-disciplinary approach to provide support and well being.

6 Relevance of Proposed Humanistic Green Governance Model

- Creating a Harmonious link between Environment and Human Progression
- Exploring core human psychological potential with Environmental function
- Rebuilding a continual resource utilization process between nature and human
- Upholding Green Governance extravaganza with holistic development
- Comprehending environmental sustainability with human work system.

7 Recommendations

Following specific suggestions can be delineated by the appropriate authorities for promotion of green practices for environmental equilibrium [7]

- To care for earth, environment and bio diversity
- To implement policies for optimum utilization of solar energy in prominent areas
- To develop policies enforcing usage of filters at industrial zone aiming towards reduction of air and water pollution
- To design mechanisms of environmental justice for providing log-lasting solutions to every level of environmental issues of human life
- To initiate a collaborative program towards building an environment of peace, harmony and equity between genders and ages, races and classes and continents across the globe.

8 Implications of the Study

In the post global-financial-crisis era engulfed with digitization, competition and fluctuations the Darwinian concept of "Survival of the Fittest" seems to the growing concern where adaptation with survival seems almost synonymous to each other. It is perhaps not surprising that the ever increasing demand of humans without understanding the real value of the various constituents of nature has led undesirable pressure and crisis on the natural resources. At this juncture environmental Sustainability is the core of better future and to make the earth a better place for living. The contribution of the society for driving a sustainable green culture and bring about enduring change in the global environment revolves around people resulting sustenance, survival and prosperity. The present study has made a modest attempt to portray the suitable strategies of green revitalization for saving our environment. Every human should develop a eco-centric view of earth-wisdom that urges us to live on this earth as a part of it with a human-centric vision. The paper therefore humbly unleashes the proposal of a model in the process of its making in order to explore the potentials of green governance vis-à-vis five identified broad independent domains. The essentiality of the study vests on the fact the motherhood essence of the nature need to restored, rebuilt and reoriented through green governance extravaganzas for healthy, sustainable and progressive living of mankind.

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Influence of Age and Ability Sensitive Ergonomics on a Workplace Design

Abdur Raoof Khan and Tarush Chandra

Abstract An ambient built environment is crucial for a universally designed physical space that significantly encourages the user's performance. Universal Accessibility is of prime importance in Architectural studies. A well-designed workspace should be friendly in terms of age and ability by taking the user's anthropometric capabilities and limitations into consideration. However, Effective evaluation of workplaces is an emerging trend that influences people's physical and behavioral performances since the working class spends a handsome amount of time at work. This research aims to heuristically evaluate the design of office spaces primarily concerning factors of age and ability-sensitive ergonomics. Professionals with specializations in Architecture, Planning, Engineering, Design were deemed as evaluators. These evaluators from different age and ability groups were targeted during an 8-h work shift. The methodology is formulated through 5 stages namely Literature study, Quessionaire formulation, Analysis, Results, and Discussion. A questionnaire survey was conducted for assessment of the perceived levels of importance and user's satisfaction with their workplace environments based on the achieved mean ratings and importance index values. The evaluation criteria were designed by taking spatial design parameters, ambient interior, and passive design into consideration. Further, the users had to choose from predefined scenarios with varied distribution levels of parameters chosen. A user ergonomics modeling has been carried out on the scenarios for developing a convenient working environment, thus increasing all users' overall productivity. The results show that the ergonomics based on these parameters can efficiently evaluate and draw conclusions for designing an inclusive work environment.

Keywords User-sensitivity · Inclusive workplace · Accessibility · Institutional productivity

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1 Introduction

The perception of human factors on Ergonomics has been evolving as a distinctive area that primarily targets human interactions with surrounding elements. Human-centric spatial design, inclusive of products and processes, has varied engineering, design, and technology implications. According to Karwowski, the particular domain can undertake application-based human behavior studies through age-sensitive dynamics. It may lead to the design of products, services, systems, tasks, and environments for effective human use and access. The ability-sensitive design approach has contributed significantly to optimizing human well-being by practical spatial configurations, thus upgrading the overall system performance and improving the general quality of life [1, 2]. Over the past 50 years, designing workplaces, commodities, and systems have drastically improved to deliver equipment and services that fit at an individual level on one's cognitive abilities. Modern-day research on ergonomics targets the characteristics of physical and perpetual attributes like human body shape, sense of human perceptions, human response to spatial and ambient conditions, and the psychological factors that contribute to a healthy working atmosphere.

2 Literature Review

The ergonomic/human factors approach adopts the anthropocentric aspects of design with a critical focus on synergy among people, systems, and the environment. The Attributes of an Age sensitive workplace have been generalized for quite some time in the early 1940s. Ergonomics was then usually followed concerning the previous knowledge bases like the Vitruvius man,[1] the Renaissance period,[2] Classical Architecture,[3] or the Modulor,[4] where architects considered body average sizes to be a rationalized medium while designing built environs. The human characteristics were often stereotyped, where differential approaches, perceptions, and responses were paid less attention. Simultaneously the cognition processes, mental and physical abilities were underestimated to a great extent. Thus, the true impact of age

[1] Vitruvius formulated the Vitruvian Man, to describe a sense of proportion for the human body by inscribing it within fundamental geometric patterns like square/circle. Further it was elaborated by Leonardo da Vinci.

[2] Renaissance was a period in European history marking the fifteenth and sixth centuries. It was derived from the Roman humanitas. It brought humanism, perspectives, observatory approaches, cognitive reasoning into existence.

[3] The classical architecture of Greeks or Romans focused on the proportional attributes of the orders with there unique aesthetic profiles and intrinsic details.

[4] The Modulor devised by the Architect Le Corbusier is an anthropometric scale of proportions. This was inspired by Vitruvius man and the work of Alberti. It covers the unique mathematical proportions in the human body which can further improve the visual appearance the architectural functionality.

and ability-sensitive groups on the built work environment was compromised in functional design, degree of independent task performance, cognitive and physical well-being [3].

Only from the 1960s, this ideology gradually considered the importance of bioclimatology and regionalism in architecture. The perceptions and behavioral dynamics of the human body were focused on the built environment [4]. Simultaneously, Environmental psychology was an emerging field of research that contributed to the importance of physical settings on human well-being. The approach was new in those times but facilitated spatial design, the psychophysical parameters of people, and passive considerations, which further modified the technical standards for ambient conditions in a built environment [5]. Spatial configurations in Architectural design have often been associated with user's preferences, activities, or both [6, 7]. It contributed to user experience in a built environment, which is of prime importance to achieve research objectives [8]. The most explicitly determined outcome of human factor ergonomics was in terms of improved productivity or performance. However, performance is critically defined as the extent to which the research goals were recognized or the relationship between the expected and accomplished deliverables [9].

Some papers have discussed the need for care or assistance facilities in the physical layout of a workplace to encourage well-being for older workers. The impact of office layout on older workers has been previously investigated, which proved to be acceptable in work cultures with nominal/less physical labor intrusive tasks or workplaces that didn't require to perform tasks with great concentration. The research contributed to the fact that open workplaces provided better opportunities for collaboration and alliance, but the task performance requiring intense cognitive and physical abilities was difficult in these settings. Most prominent studies are aligned towards the realization of spaces within a workplace to encourage a positive attitude among employees for a better working potential. It is achieved by focusing on balanced environments with proportional open and quiet areas within the workplace [7, 9].

3 Human-Centric Design Factors in a Work Environment

Humans are complex psychological and physiological beings. Owing to the amalgamation of age, ability, experience, level of education, physical fitness, mental well-being, deep-rooted instincts, cultural and social values, every individual is exclusive [10]. Thus, it complicates forecasting comfort, safety, and convenience since it cannot be regulated or monitored. Accordingly, the workplace environment may set dynamic responses among individuals, depending upon their cognitive states of mind, physical constraints, and psychological tendencies. The ergonomic/Human Factors approach has a proportionate distribution of built and green spaces since both are important in affecting the user's performance.

3.1 Factors of Ambient Indoor Conditions

The thermal environment has a deliberate effect on humans since it is associated with their thermal comfort and physical attributes. All the other factors of climatology like Relative humidity, Atmospheric pressure, Air and surface temperatures, wind velocity, etc., have a significant influence on humans. The type and insulation of clothing, psychological conditions, physical abilities, and metabolic rate influences humans' overall response mechanism [11]. Owing to ability constraints, anxieties, or other age-related complications, older people are sensitive to fluctuations in climate and less adaptive [12]. The human factors associated with vision and non-visual functions in a confined workplace are analogous with the natural spectrum of daylight with balanced colors and respective wavelengths [13]. Equivalently, indoor air quality is crucial in determining the levels of comfort and convenience in workplaces. It is identified as a combination of the CO_2 level, temperature, and relative humidity within the spatial boundaries, varying according to regional climates, wind flow, or sunlight. Thus, older people tend to be less comfortable indoors at higher temperatures or humid working environments if there is no air conditioning [14]. Auditory levels within a confined workplace may also be responsible for influencing a built environment's human perception. Aged people are more susceptible to noise than younger. Ambient sound within interior spaces is less noticed under nominal levels but causes distractions and psychological trauma when they become sporadic or exceed standard levels.

3.2 Factors of Space Design and Ergonomics Within a Workplace

A substantial aspect of space design is associated with the inclusiveness of activities within a workplace that encourages age and ability-sensitive resources. Examples within inclusive workplaces include U-shaped door or storage handles, push latches, ramps, adjustable chairs, multi-sensory safety alarms, and access to all. Also, the

Table 1 General parameters considered for ambient interior quality

Parameter	Unit	Excellent class	Good class	Limit for IAQ
Air temperature	^{o}C	20 to <25.5	<25.5	22.5–25.5
Airborne bacteria	cfu/m^3	<500	<1000	500
Relative humidity	%	40 to <70	<70	<−70
Suspended particles (PM_{10})	μg/m^3	<20	<180	150
Carbon dioxide	ppmv	<800	<1000	1000
Carbon monoxide	ppmv	<1.7	<8.7	9

Source NEA office IAQ guidelines manual

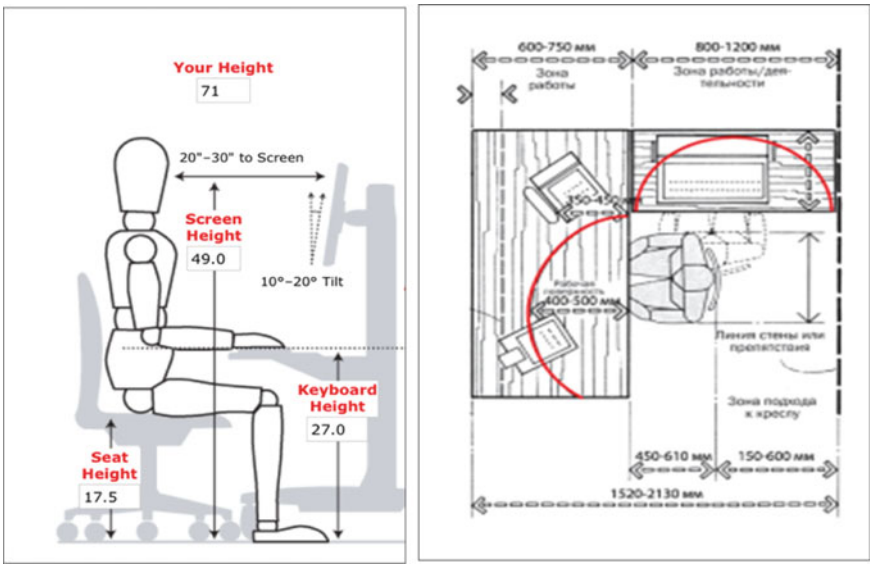

Fig. 1 Anthropocentric and workstation ergonomics criteria for a workplace. *Source* Ergonomics workstation assessment manual, Healthworks

user-specific requisites should be taken into account while planning the workspace. Common areas within a workplace are the prime locations that should be accessible for all. They include dedicated parking spaces, entry and exit locations, ramps, stairs, elevators, lavatories, restrooms, open areas, and workstations [15]. The space standards consideration is crucial in the design of an inclusive workplace. It is also essential to enable equitable distribution of workspace to satisfy the users' actual needs without compromising their comfort and safety. The anthropocentric and workstation ergonomics as mentioned in Fig. 1 should adhere to the functionalities of the workplace like the efficient layout, surface area for specific tasks, shared spaces for all user categories, personal workstation ergonomics for employees, comfortable furniture, adequate storage, shared equipment, and social spaces. Some of the technical aspects are dedicated to upkeep the safety of users, like fire evacuation plans, sprinkler systems, types of fire extinguishers, emergency lighting, alarm systems, etc. [15]. Some of the other considerations include adequate width of passages without hindrances, fireproof equipment, fire-resistant furnishings, etc.

3.3 Passive Considerations

Work performance is affected by human-centric factors like a sense of belongingness, work-induced stress, mental health and well-being, physical constraints, contributing to performance gaps of up to 40% [16]. Research of several biophilic environments

has talked about the positive impact of natural landscapes over urban landscapes in the workplace. In one such case study from France, Office workers showed the most significant mental well-being due to nature scapes, indoor green spaces, and positive views compared to urban settings [17]. Colour has been identified in many kinds of research as an essential aspect of spatial design. Different colors are associated with different moods or mindsets, like blue is the color of water, medium, and darker greens signify healthy vegetation, yellow is a sign of drying vegetation. It is commonly regarded as the "ecological valence theory" [18]. The same colors can create different responses among people working in an environment like dark green for relaxation, yellow for excitement, and red for high concentration.

4 Methodology

The detailed research methodology has been explained in Fig. 2. The research is divided into five stages: Literature review, Factor identification through desktop

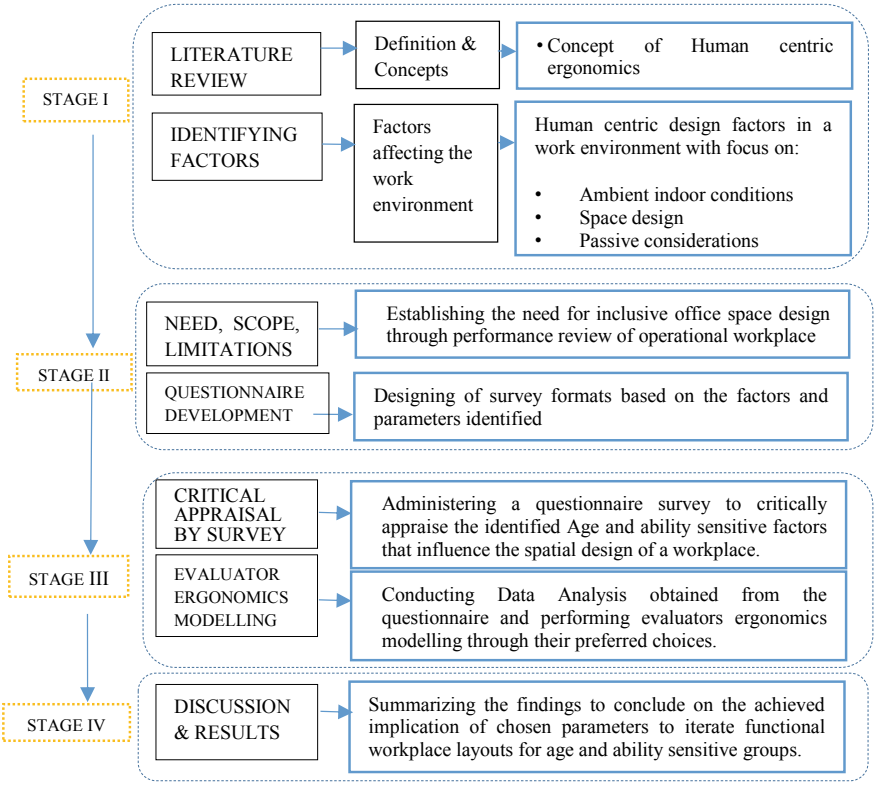

Fig. 2 Research methodology

study, Questionnaire development, Critical appraisal, User ergonomics modeling, Results, and Discussions.

4.1 Need, Scope, and Limitations of the Research

Age and ability, sensitive ergonomics in a workplace, is a necessary, cost-effective solution that can be achieved through appropriate spatial design considerations to manifest upon increased comfort, work efficiency, and mental well-being. In light of sustainable office design, it is essential to determine the quality of services provided in a workplace, leading to increased users' efficiency. This research is carried out to assess the performance of the various architectural and planning firms in India. The assessment is limited to professionals' views having specialization in Architecture, Urban planning, Transportation Planning, Engineering, and Design.

5 Data Collection and Analysis

The data collection was conducted through a questionnaire survey to gauge the evaluators' level of importance and satisfaction concerning ten factors described in Table 1, specifically under the parameters of Spatial design, Ambient Interior, and Passive considerations. Initially, the multi-attribute utility approach [19] analyzes the respondent's ratings to compute a mean rating point (M.R.) as a measurable criterion to assess the degree of influence considered factors under each group of parameters. The response aggregates were calculated for all the factors. The MR for each factor was achieved by summarizing product ratings associated with each scaled term and percentages of an unlimited number of responses related to each factor. The relative importance index (R.I.I) for each factor was then cumulated by dividing the M.R. with the sum of all M.R.s of considered factors within each bracket of parameters. The next stage of User accessibility modeling was done by the choices made by the evaluators from the predefined scenarios consisting of percentages distribution of factors for spatial design, ambient interior, and passive design considerations.

6 Results

6.1 General Highlights of Evaluators

The evaluators were composed of 36% Architects, 32% Planners, 7% Designers, 18% Engineers, and 7% Administration staff. 28% of evaluators were of the 25–35 years age category, followed by 25% of evaluators between 35 and 45 years, 21%

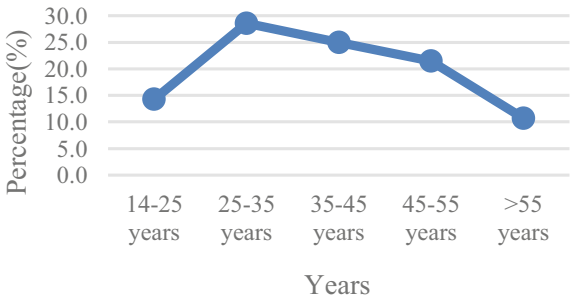

Fig. 3 Age of evaluators

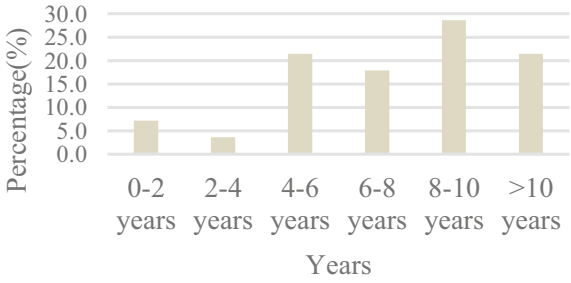

Fig. 4 Work experience of evaluators

of evaluators between 45 and 55 years, as shown in Fig. 3. About 25% of evaluators had between 8 and 10 years of experience in the current workplace, followed by 21.4% of evaluators who had more than ten years of experience in the present workplace, as shown in Fig. 4. It infers that many respondents had a better understanding of the planning and anthropocentric dynamics within the current workplace.

6.2 Response Highlights of Evaluators

Spatial design parameters have been subdivided into four factors, as mentioned in Table 1, for understanding the level of importance for the evaluators. They are rated into five levels of importance and satisfaction: most important/satisfied, very important/satisfied, moderately important/satisfied, slightly important/satisfied, and not important/satisfied. The defined seating and Accessible workstation ergonomics have the highest mean rating and relative importance index values determining the highest degree of influence belonging to various age and ability groups. It is followed by the factors of safe and comfortable Entry/Exit points and Equitable access of space to all. The exact sequence is visible in terms of Levels of satisfaction among the evaluators. Seating and workstation ergonomics provide a greater level of satisfaction to all the evaluators in their respective workplaces. The parameters of Ambient Interior considerations have been divided into three factors, as mentioned in Table

1. Indoor air quality and thermal comfort have the maximum mean rating and relative importance index values followed by ambient auditory levels and Luminous quality factors. It highlights the maximum degree of influence by the evaluators on the ambient interior considerations based on these factors. The passive concerns have been subdivided into the factors mentioned in Table 2. The factor of Signages, Safety measures, and Evacuation layouts received the highest M.R. and R.I.I. values, followed by the factor of indoor green spaces based on the levels of importance and

Table 2 Age and ability sensitive parameters with their respective factors influencing the workplace design along with their M.R. and R.I.I. values

Spatial design context	Level of importance (in %)								
	MI	VI	Mo. I	SI	NI	TR	MR	RII	%
1. Comfortable and safe entry/exit points in workplace/office	28.57	53.57	10.71	7.14	0.0	28	4.0	0.25	25
2. Defined seating ergonomics for all	35.71	42.86	17.86	3.57	0.0	28	4.1	0.26	26
3. Equitable use/access of space and common areas by all	14.29	53.57	21.43	7.14	3.5	28	3.6	0.23	23
4. Work station ergonomics based on universal specifications of accessibility	39.29	39.29	21.43	0.00	0.0	28	4.1	0.26	26
Spatial design context	Level of satisfaction (in %)								
	MI	VI	Mo. I	SI	NI	TR	MR	RII	%
1. Comfortable and safe entry/exit points	0	25	60.71	14.29	0	28	3.1	0.25	25
2. Defined seating ergonomics for all	7.14	25.00	46.43	17.86	3.5	28	3.1	0.25	25
3. Equitable use/access of space and common areas by all	0.00	17.86	50.00	28.57	3.5	28	2.8	0.23	23
4. Work station ergonomics based on universal specifications of Accessibility	3.57	42.86	39.29	7.14	7.1	28	3.2	0.27	27
							12		
Ambient interior context	Level of importance (in %)								
	MI	VI	Mo. I	SI	NI	TR	MR	RII	%
5. Ambient auditory levels in a workplace/office	10.71	57.14	28.57	3.57	0.0	28	3.7	0.32	32
6.Indoor air quality and thermal comfort	42.86	35.71	21.43	0.00	0.0	28	4.2	0.36	36
7. Light/luminous quality within a workplace/office	21.43	46.43	28.57	0.00	3.5	28	3.8	0.32	32
							11		
Ambient interior context	Level of satisfaction (in %)								
	MI	VI	Mo. I	SI	NI	TR	MR	RII	%
5. Ambient auditory levels in a workplace/office	7.14	14.29	50.00	10.71	17	28	2.8	0.30	30

(continued)

Table 2 (continued)

Spatial design context	Level of importance (in %)								
	MI	VI	Mo. I	SI	NI	TR	MR	RII	%
6.Indoor air quality and thermal comfort	14.29	32.14	42.86	10.71	0	28	3.5	0.37	37
7. Light/luminous quality within a workplace/office	3.57	39.29	32.14	14.29	10	28	3.1	0.33	33
							9.4		
Passive context	Level of importance (in %)								
	MI	VI	Mo. I	SI	NI	TR	MR	RII	%
8. Landscape/indoor green spaces	17.86	46.43	21.43	10.71	3.5	28	3.6	0.33	33
9. Signages, evacuation layouts, safety measures within a workplace/office	28.57	46.43	21.43	3.57	0.0	28	4.0	0.36	36
10.Availability of ramps/elevators	21.43	28.57	32.14	17.86	0.0	28	3.5	0.32	32
							11		
Passive context	Level of satisfaction (in %)								
	MI	VI	Mo. I	SI	NI	TR	MR	RII	%
8. Landscape/indoor green spaces within a workplace/office	0.00	32.14	32.14	17.86	17	28	2.7	0.3	33
9. Signages, evacuation layouts, safety measures within a workplace/office	7.14	28.57	32.14	25	7.1	28	3.0	0.36	36
10. Availability of ramps/elevators	10.71	17.86	25	21.43	25	28	2.6	0.32	32

Table 3 Predefined Scenarios for evaluators choice

	Spatial design (%)	Ambient interior quality (%)	Passive considerations (%)
S1	5	2.5	2.5
S2	2.5	5	5
S3	2.5	2.5	5.0
S4	2.5	2.5	2.5

satisfaction of evaluators. It is significant since the passive considerations of adequate safety measures, evacuation layouts, and signages are deemed most important in the design of workplaces. Further, the factors with the highest importance ratings are used for user ergonomics modeling.

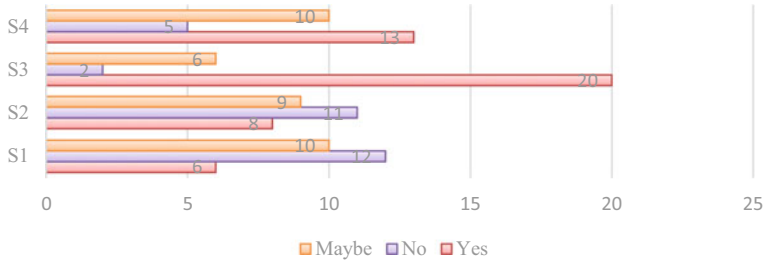

Fig. 5 Likelihood of evaluator's choice of scenarios for ergonomics modelling

6.3 User Ergonomics Modelling

The final stage of this research was to conduct a user ergonomics modeling where evaluators were asked to choose from predefined scenarios as mentioned in Table 3, comprising different distribution levels for the parameters discussed above that would create comfortable, safe, and convenient working environments. Under-considered parameters with the highest mean ratings and importance index values have been used for the modeled criteria with anthropometric specifications. Thus under Spatial design, the considered elements are seat height, adjustable screen height, keyboard/seating elbow height, eye to the screen width, workstation width, workstation length, and movement width. Under Ambient interior quality, the elements include Air temperature, air movement, Illumination, Acoustics, relative humidity, PM10, Carbon dioxide, and Carbon monoxide suspensions. Under Passive considerations, the elements include the number of green space locations, locations for evacuation plans/layouts, and locations of ramp/elevators.

The likelihood of choice, as mentioned in Fig. 5, corresponding to a 71% inclination for the third scenario and a 46% inclination for the fourth scenario. Hence the obtained values for the considered factors corresponding to those scenarios have been mentioned in Table 4. These scenarios were most favorable by a majority of evaluators. Correspondingly, the universal guidelines for the below-mentioned parameters have been compared to the achieved values, which are well within the range.

Table 4 Parameters considered for user ergonomics modeling based on the likelihood of choice

	Spatial design (2.5% increase)	L	M	H		Spatial design (2.5% increase)	L	M	H
S3	Seat ht in mm	359	456	615	S4	Seat ht in mm	359	456	615
	Adjustable screen ht in mm	1204	1276	1384		Adjustable screen ht in mm	1204	1276	1384
	keyboard/sitting elbow ht in mm	687	702	718		keyboard/sitting elbow ht in mm	687	702	718
	Eye to screen width in mm	521	651	779		eye to screen width in mm	521	651	779
	Workstation width in mm	1558	1794	2183		workstation width in mm	1558	1794	2183
	Workstation length in mm	1558	1794	2183		workstation length in mm	1558	1794	2183
	movement width in mm	359	461	615		movement width in mm	359	461	615
	Ambient int. quality (2.5% increase)	L	M	H		Ambient int. quality (2.5% increase)	L	M	H
	Air temperature in °C	23	25	26		Air temperature in °C	23	25	26
	Air movement in m/s	0.23	0.26	0.29		Air movement in m/s	0.2	0.3	0.3
	Illumination in lumens/sqft	512.5	615.00	768.7		Illumination in lumens/sqft	513	615	769
	Acoustics in Db	25.6	30.75	35.88		Acoustics in Db	26	31	36
	Relative humidity in %	41.0	53.30	64.58		Relative humidity in %	41	53	65
	PM10 in $\mu g/m^3$	123	153.75	184.5		PM10 in $\mu g/m^3$	123	154	185
	CO_2 in ppmv	615	717.50	820.0		CO_2 in ppmv	615	718	820
	CO in ppmv	1.74	4.10	8.92		CO in ppmv	2	4	9
	Passive considerations (5% increase)	L	M	H		Passive considerations (2.5% increase)	L	M	H
	Green spaces in no. of locations	3.2	5.3	8.4		Green spaces in no. of locations	3.2	5.3	8.4
	Signage, safety plans no. of locations	2.1	4.2	7.4		Signage, safety plans no. of locations	2.1	4.2	7.4
	Ramps/elevators no. of locations	2.1	5.3	7.4		Ramps/elevators no. of locations	2.1	5.3	7.4

7 Discussion

Having established the sensitive nature of various design parameters in controlling the dynamic functions of a Workplace, This research has a novel approach in establishing the user's perspective in a statistically relevant manner. The highest mean ratings and indices of chosen parameters have been used to develop the scenarios for the selection of the most favorable alternative by individual choice. The results show that based on the individual preferences, the spatial, ambient interior and passive design parameters can be significantly addressed to achieve a workable environment for all categories of users. Previous research has established the importance of designing workplaces to suit the area specifications and improve the progressive performances of users. However, this research has targeted improvising the underlying considerations within each bracket by modeling specified user-based choices. This schematic approach has given positive outcomes well within the acceptable ranges of workplace ergonomics.

8 Conclusion

Owing to the dynamic fields of applying human-centric ergonomics in workplaces, the possibilities of research are abundant. This research proved beneficial in users' perspectives in workplaces where individual choices of specific factors defined ergonomics can be adjusted to improve overall performance and productivity. The research framework can be standardized to monitor the level of satisfaction among employees concerning the age and ability friendliness of configured workplaces. Further possibilities of this research can be in terms of biophilic design interventions, digital technology, and intelligent energy systems to enhance the user's experience in a defined work environment.

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Sustainability: Indian Cultural Heritage Through Game Design Concept

Swarnadeep Nath, Subash Rai, Bhaskar Saha, and Debkumar Chakrabarti

Abstract Indian heritage monuments are affected throughout the years by a variety of physical and biological pressures. This study explored the potential of game design as a medium that can be designed to sustain cultural heritage and natural history of ancient Buddhist cave monuments in India of various historical eras. Games and simulations can provide an atmosphere in which users can construct new facts of socio-cultural development and creative thinking knowledge integration. This paper is an attempt to understand Indian cultural heritage through the game design concept for pre-production planning, and eventually, enhance Indian enormous cultural and historical values into the domain of public knowledge. In order to validate the relevance of the study, the significant findings were reviewed and summarize the research design approach. Based on the input and discussion with professionals, it was determined that game design concepts based on Indian heritage would certainly provide users with the positive reinforcement they require. Furthermore, such game design with an indigenous prospect can allow users to re-create themselves into a new realm while providing opportunities for meaningful learning.

Keywords Sustainability · Heritage · Visual communication · Game design · Cognitive ideas · Animation

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1 Introduction

Indian cultural heritage are extremely valuable to society, community, and nation as they represent the past and uniqueness of the place [1]. Cultural heritage has a wide range of meanings and it has been constantly changing over the time. Initially, it was covering only tangible heritage, such as architectural monuments, landmarks, and sites; but, as time passed, it expanded to include all intangible dimensions as well. Heritage is now described as "an expression of a community's ways of life established over time and passed down from generation to generation, including traditions, practices, locations, monuments and other artistic expressions, and values" [2]. Heritage sites and architectural monuments all over the world have been found to have deteriorated dramatically due to various biological factors in recent decades [3]. The Archaeological Survey of India manages and conserves many historical buildings and heritage monuments, which are rich in cultural and historical ideals [4]. Many of these ancient heritage monuments are found in remote areas far from human settlements, such as forests and pristine areas. Some of India's famous cave monuments include Ajanta, Ellora, Bhaja, Karla, Bedse, Kanheri, Elephanta, Udayagiri, and Khandagiri [5]. The Ajanta Heritage Monument (Fig. 1), is a set of rock-cut Buddhist caves that are human marvels and showcase artistic and technical achievement [6]. These caves include painting of Hinayana and Mahayana beliefs of Buddhism, as well as rock-cut sculpture mentioned as among the best preserved examples of ancient Indian art [7]. The caves were lost in obscurity until British Battalion Officer Mr. John Smith rediscovered them in 1819 [8]. Since 1983, UNESCO has designated the Ajanta Caves as a World Heritage Site [9]. In 1995, the Indian government designated Ajanta Caves as a national and heritage monument [10]. The Archaeological Survey of India began protecting and preserving Ajanta caves, rock carvings as well as paintings [11].

In this paper an attempt has made for a digital game as a medium that can designed to sustain cultural heritage and natural history of ancient Indian Buddhist cave monuments of various historical eras, hence a special reference has been taking into account that is Ajanta Caves. However similar instances and examples have been discovered in various ancient cave monuments and heritage sites throughout the country.

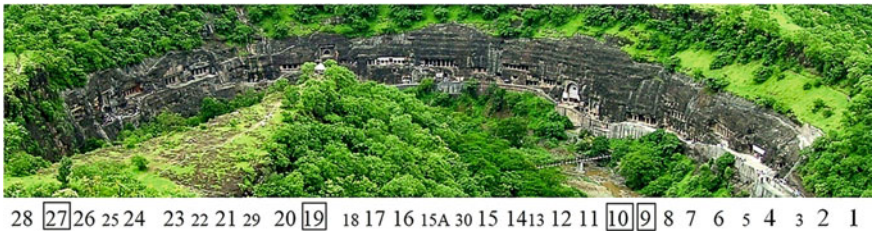


Fig. 1 Ajanta Caves, panorama with cave numbers. The caves are numbered from right to left, except for the later discovered cave 29, located high above cave 21. Also, cave 30 is located between caves 15 and 16, nearer the river bed (cave invisible here). Chaitya halls are boxed (9, 10, 19, 26), and minor caves are indicated by a smaller type [12]

1.1 Digital Gaming: Indian Landscape and Cultural Depiction

India is a developing market for video games. The video game market in India is expected to expand as investments continue to increase [13]. When it comes to implementation of digital games based on Indian settings and culture it incorporates element from history, architectures, mythology, music so on. Indian game developers, has mostly been attempts to produce Indian heritage or culture based games on a bigger scale [14]. *Asura's Wrath* is published by Capcom, an action game created by Cyberconnect2. Asura's Wrath was first unveiled in 2010 at the Tokyo Game Show and was published internationally in February 2012. The most advanced game which takes elements from Hindu mythologies and mainly incorporates Indian architectural landscapes setting and blend into fiction [15]. *Call of Duty: Modern Warfare 3:* (first-person shooter video game) developed by American Video Game developer, Infinity Ward and Sledgehammer Games (2011), With barely a hint of Indian environment [16], the campaign featured a single mission set in the Himachal Pradesh city of Dharamshala. Games like *Smite: (Multiplayer online battle arena)*, produced by Titan Forge Games and published by Hi-Rez Studio, an American video game company, in 2014, on the other hand, tend to bend characters from Indian mythology to suit the game's needs [17]. However, *Assassin's Creed Chronicles: India*, produced by Climax Studios and released by Ubisoft, a French video game company, is one title that is clearly more dedicated to precise portrayal of India. An offshoot of the main series, *Assassin's Creed Chronicles: India*, is set in a booming city of sandstone and features a masked explorer in the midst of the Sikh War of 1841. The mission is to recover the famed Koh-i-Noor diamond for the good of mankind—while killing a bunch of Sikh enemies along the way [17].

1.2 Video Games on Contemporary Society: Impact Analysis and Interpretations

Video games have established as a medium of entertainment over the years. Most obviously, enormous technical advancements have enabled designers to create advanced digital environment. Video game production has progressed significantly, and today's gaming experience is much more diverse than earlier. Action games are still popular, but simulations, strategy, role playing, sports, puzzles, and adventure games are becoming increasingly popular [18]. Many educators have raised their concerns about video games' effect on learners, as well as the wisdom of incorporating more video game technology into the classroom [19]. One of the most prominent video game critics, Provenzo, addresses four major issues about video games: (a) Can lead to violent, aggressive behaviour; (b) Use negative gender stereotyping; (c) Promote unhealthy "rugged individualist" attitudes; and (d) Suffocate cognitive development [20]. Some of Provenzo's statements are certainly true. Many

video games still have storylines that directly relate to "kill or be killed," and many games have themes, which, if accepted uncritically are potentially destructive. With the rise of progressive educational ideas and a shift toward more experiential and student-centered learning, there has been a surge of interest in using simulation and gaming in the classroom. Another driver for the use of computer-based simulations and games in teaching is the growth and expanded use of e-learning [21]. Since its inception in the late 1970s, computer games have increased the attention and time of countless children and youths all over the world, and their obsession with digital gaming is stronger than ever [22]. In the twenty-first century video game playing increased among children and youths in Indian, because of the advent of digital game has emerged social spaces on various platforms such as computers, mobile phones, gaming consoles etc. [23]. However, as digital games have become a more common occurrence in people's lives, the audience's potential consequences have started to be debated. The key issues have revolved around the fact that playing video games can become addictive or lead to other negative behaviours like violence or depression. It is possible that educational video games can provide that missing motivation of students thereby making them an excellent educational and teaching tool. Correspondingly, a number of studies have identified certain advantages of using video games in education in that they motivate learning through challenges, stimulate exploratory behaviour and the desire to learn, improve cognitive skills and enhance knowledge in account of socio-cultural and historical perspectives.

2 Research Gap

Considering the above literature reviews, a digital game is proposed as a tool for sustaining India's cultural heritage. There are currently few methodologies for creating educational video games, and those which mostly exist denote science and maths solving problems. This paper, therefore, presents a new game design approach which will help in sustaining Indian cultural heritage monuments of Buddhist cave monuments and history that integrates in game aspects. There is hardly any study that has conceptualised the above analysis based on specific dimensions and propositions.

3 Aim

In this paper an attempt has been made to propose a game design concept for pre-production planning towards sustaining Indian cultural heritage, in particular ancient Buddhist cave monuments as game themes. Therefore, as a special reference to Ajanta caves has been taken into account.

4 Objectives

The objective of this study is to create a game design concept as an educational medium for providing an environment for the learner's construction of new facts of social and cultural development and enhancing academic abilities, creative thinking and knowledge integration. On that account create an immersive game design concept that can be used as educational resources while also encouraging the young generation to enhance their knowledge on Indian culture and heritage through gameplay.

5 Sampling

There were 13 numbers (n = 13) participants, which includes the industry and academic experts, i.e. 2D, 3D gaming artists, visual designers, per-production and concept artist, academicians from diverse background, research scholar along with the design based students has been participated in the discussion through virtual and physical mood.

6 Pragmatic Approach

To investigate the research objectives, interview and discussion session was conducted with academicians from the various backgrounds since they examined learners more frequently and have a better understanding of their psychology. Further discussion was also conducted with academicians from the department of art history and aesthetics as they have a greater understanding of different eras' history, culture, heritage monuments and its aesthetics values. Industry experts were also participated in the discussion and interview session as they have an extensive knowledge in this specific area. Selected research scholars and students who are working on sustainability and Indian heritage development have also participated in the thorough discussion. In the context of mentioned discussion session, the feedbacks and outcomes are listed in Table 1.

The interview questions were formed based on the need of the research domain. Participants' opinions have been taken to evaluate whether popular digital games still need to redefine the way games are evolving? Further investigation on if the digital game provides significant knowledge to learners leading to accumulating and sustaining Indian cultural heritage was opined. Also, there was an examination on the video games design's effects on cognitive development both positively and negatively. The study's findings were used to guide the design method process and the final game design and stages were developed shown in Fig. 2. In order to verify the relevance of the works reviewed, the key findings were investigated and summarized research design methodology. The findings and feedback were overwhelmingly

Table 1 Feedback and discussion with various eminent personalities

Name	Designation/organization	Feedback of the discussion
Mr. Subendu Bhattacharjee	Senior Game artist, Technicolor. India. PVT. LTD, Bangalore	The topic can be explored in depth in order to implement it as a tool for learning
Ms. M Nath	Assistant Teacher. Jarailtola, M.E School, Assam, India	Desire for digital games is too high in school children. Such game concepts can be employed in students for better understanding of Indian tradition and heritage
Ms. Chaitali Brahma	Registrar, Central Institute of Technology, Kokrajhar, Assam, India	This study will help to create interest amongst young minds to go to their roots and develop interest for further quest of knowledge
Mr. Ashar Alam	Pre-production Artist at DNEG, Indian, Pvt. Ltd, Chennai	Overall game environment, character, set, props designs should be very exciting in production level
Mr. Pinak Pani Das	Senior Game Artist, Zynga, Bangalore, India	Based on learning games, simulations are very popular. Commercial success of the game as well
Mr. S. N Choudhary	Team Lead, Rockstar Game and Animation Pvt. Ltd, Bangalore, India	Important to sustain educational contents in digital games, but at the same time to connect users it is important to use attractive visuals, FX and surrealistic approach for the same design concept
Mr. Krishna Vanaparthi	3D texturing artist, DNEG India. Pvt. Ltd. Chennai, India	Planning a game concept based on Indian religious monuments and the ethical aspect of the concept needs to be maintained
Mr. Sandipan Bhattacharjee	Student, M. Des, Central Institute of Technology, Kokrajhar. Assam, India	It is an exciting approach for learning aspects
Mr. Ramakrishna, G.	Assistant Professor, Department of Multimedia Communication & Design, Central Institute of Technology, Kokrajhar, Assam. India	Need for implementation in Indian society, which will help the young generation to develop their knowledge on Indian Tradition and Heritage through game play

(continued)

Table 1 (continued)

Name	Designation/organization	Feedback of the discussion
Mr. Sudip Das	Asst. Professor, Art History and Aesthetics, Maharaja Sayajirao University, Baroda, Gujarat, India	Interesting study, considering the religious and ethical value of the historical monuments
Mr. Sudipto Nath	Animation Designer and 3D Character artist in Anibrain VFX, Pune, India	A positive solution of digitization for learners as well as those who are addicted to digital games
Ms. N. Pranab	Computer Teacher, K. V, Silchar, Assam, India	Essential to support Indian games on such concepts for education purposes
Mrs. B. Papri	Assistant Teacher, Raja G. C Memorial H.S School. Borkhala, Assam, India	Digital games may lead to violent, aggressive behavior among learners Important to avoid such depiction while planning any digital game design concepts

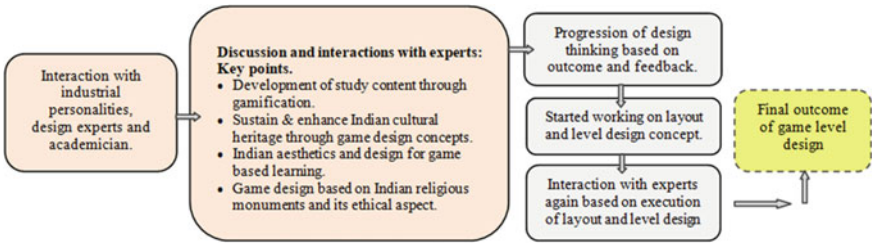


Fig. 2 Design method process

positive, showing that using games to teach about Indian cultural heritage can be an effective and engaging way of learning.

7 Outcome and Design Diagram

Game description and concept have been designed based on the above input and discussion with three primary levels. Concept stages refer to Fig. 3.

The current approach is intended to create a prototype workflow for pre-production planning; later stages will include actual interaction, design, and development.

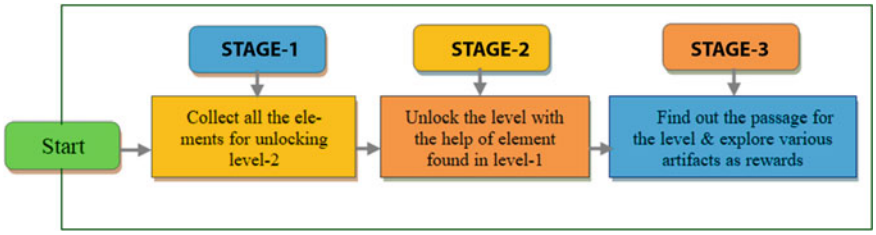


Fig. 3 Basic layout and objectives of game stages

7.1 Game Overview and Approach

The Ajanta heritage monument is a collection of about thirty rock-cut Buddhist caves; refer to the cave map (Fig. 4) [24]. These caves include paintings depicting Buddhism's Hinayana and Mahayana doctrines, as well as rock-cut sculpture that are considered one of the greatest preserved examples of ancient Indian art. In this design concept all the game elements are extracted from Hinayana and Mahayana period, which are two main classifications of Buddhism. The overall design approach seeks to capture both the spirit of adventure as well as the historical component of the caves and their significance. The game contains clues and moral values that have been narrated throughout game play. For this case study, three different Ajanta caves have been chosen: caves no. 1, 9, and 19, as shown in Figs. 5, 6, and 7. Particular game design has been divided into three levels, each of which contains a specific cave and its relevant information.

Game concept is a role-playing and adventure game genre; based on Indian setting, where users must explore several caves one at a time to complete assigned tasks and collect information about the cave monuments while overcoming various obstacles and challenges. Users have to retain the maximum amount of energy level from the

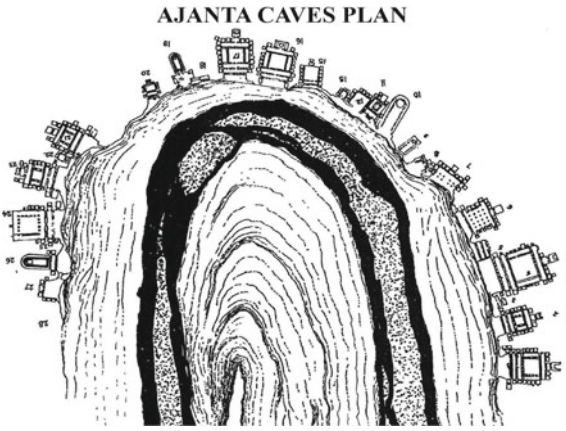


Fig. 4 Ajanta caves plan [24]

Fig. 5 Cave no. 1

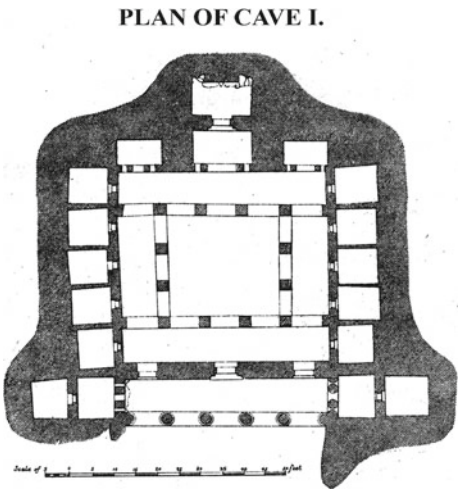
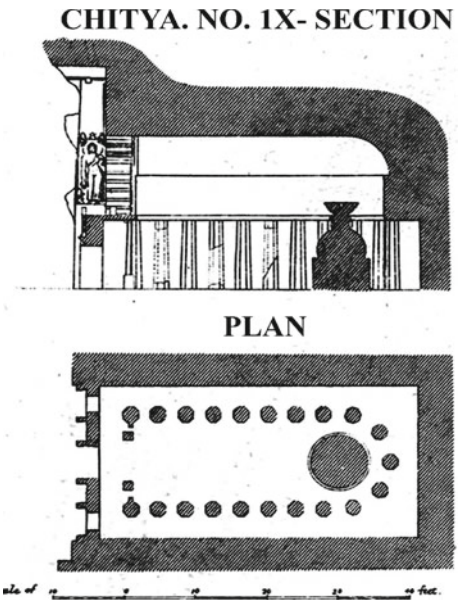


Fig. 6 Cave no. 9



damage or loss of stamina that they can collect during the play to avoid them dying from exhaustion. Throughout gameplay if the user loses consciousness to fulfill the challenges then they need to restart the game from the preceding level that is the last cave one player has already explored.

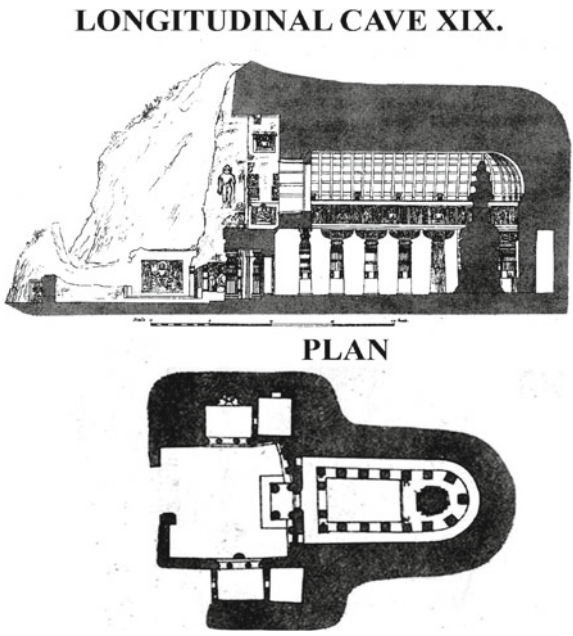


Fig. 7 Cave no. 19 [25]

7.2 Design Brief: Game Flowchart and Level Concise

The platform used might be a PC, console, or smartphone/tablet, and the users for the game could be anyone (e.g. School students). This design approach includes a main character and other supporting characters they assist the main character while completing various tasks throughout the play. Furthermore, the educational aspect has been split between the play actions and dialogues as well as the other existing game elements. An inscription on cave walls or paintings, game rewards for example, that provides specific information to solve a learning challenge or an interaction with the subject matter. The complete game design concept combines three different levels for the system integration.

7.3 Level Design: Level 1, Cave No. 1

The paintings that have been preserved on the walls, ceilings, and pillars of Ajanta Cave 1 are well-known. According to Spink, the effort was funded by the Vakataka Emperor Harishena. The scenes depicted from the *Jataka* accounts of the Buddha's earlier lives as a bodhisattva, the life of the Gautama Buddha, and those of his veneration are largely devotional, and ornamental. *Bodhisattvas Padmapani, Sibi, Sankhapala* and *Vajrapani* are the most famous individual fresco paintings in Ajanta cave 1 [26]. The game begins with cave narratives, in which all relevant information

Fig. 8 Ashtamangala, eight auspicious signs Hinduism, Jainism, and Buddhism [27]

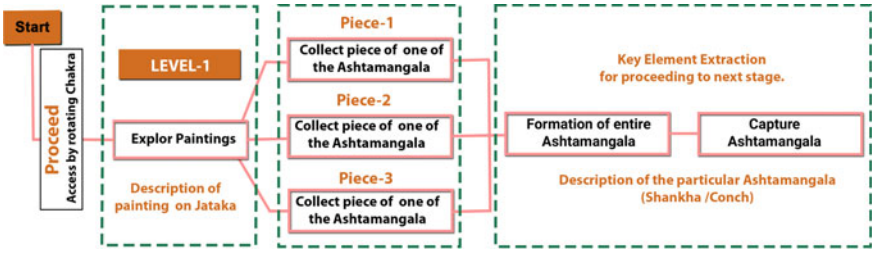


Fig. 9 Flowchart of level 1, cave 1

will be designed in voiceover, allowing users to access the road map to the *first level, cave no. 1*. Character must access the doorway by rotating *Dharmachakra*/ wheel of law (an auspicious symbol of Buddhism, represents Gautama Buddha and the Dharma teaching). This particular chakra will be filled with *Ashtamangala* (a sacred group of eight auspicious signs to a number of religions such as Hinduism, Jainism, and Buddhism) [27], shown in Fig. 8, in which the user must attend one of the *Ashtamangala* by spinning Chakra to access the doorway for the *level 1*, referred to flowchart (Fig. 9).

Once character enter the cave will notice all the jataka paintings from where user need to collect all the information of these paintings and from each painting user will receive a reward as a pieces of one of the *Ashtamangala* from each painting, finally which will form one of the entire *Ashtamangala* that is *Shanka*/Conch for access to the next level. However, various elements, credit points and health will be received during this level.

7.4 Level Design: Level 2, Cave No. 9

This cave consists of a freestanding *Stupa* (that is used as a place of meditation) at the center of the apse, with a circumambulation pathway around it. On the left wall of the cave are votaries approaching the *Stupa*, implying a devotional tradition, shown in Fig. 6. Walls are painted with *Jataka tales* (stories of the lives of the Buddha found in Buddhist literature), they were presumably added in the fifth century during the Hinayana period of construction [26]. Level 2 (Fig. 10), associated with the previous level. In order to reach this level users, have to save his/her life from the various

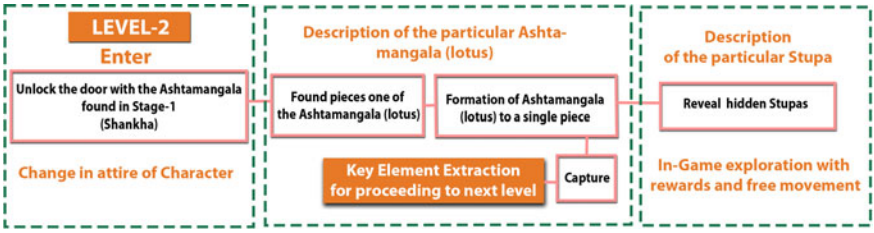


Fig. 10 Flowchart and framework of level 2, cave 9

obstructions. Moreover, user must collect several information during the passage which will help to accomplish this level. Once arriving at the level, the user needs to unlock the cave doorway with the help of one of Ashtamangala found in the previous level, which is conch.

In the second stage, the user must find a location inside the cave where a distorted *Ashtamangala* has been displayed on the cave wall that should be combined in a sequence with a precise time in order to produce a complete one of the other *Ashtamangala* which is *lotus sign.* Once the user grabs the lotus, a hidden *stupa* will appear; however, the narration will continue and provide significant information about the *stupa* and the cave. In order to complete this level finally, users must collect various information and rewards with free movements.

7.5 Level Design: Level 3, Cave No. 19

Cave 19 is a fifth-century CE worship chamber and one of the caves noted for its sculpture. It features Naga figures with a serpent canopy protecting the Buddha, similar to those seen in ancient Jain and Hindu traditions [26]. In this level, elements have been referred from cave no. 19. The primary challenge of this level is to find the cave location as this level consists of five different routes including the main entrance. Each route designed refers to a certain purpose such as collecting various elements related to this cave, rewards, health and information; refer to flowchart (Fig. 11).

The main challenge of this level is to enter to the main cave, however users have to hold the maximum amount of energy level from the damage or loss during the play to avoid them dying from collapse. Design flow of this level is divided into two major stages. In the First stage users need to unlock the entrance with the help of one of the *Ashtamangala* that is lotus found in the level 2, and explore various artifacts as rewards related to cave monuments, therefore all the descriptions of artifacts will be narrated for learning outcome. In the second stage where the user will notice a *stupa* with a depiction of Buddha, the user must approach the *stupa* and listen to the visual supporting explanation from which the user will collect relevant information for approaching next levels. In this design concept all the information related to the

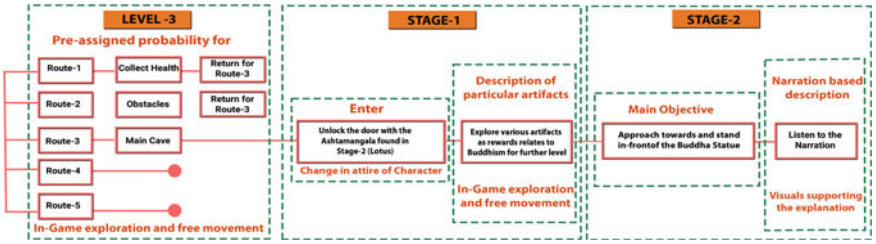


Fig. 11 Flowchart and framework of level 3, cave 19

caves will remain genuine, only visual elements can be designed and represented in an imaginary approach by considering all the ethical aspects of the caves and its religious value. The design planning described above can be implemented in all the caves of *Ajanta* with a range of levels design and planning. As the level increases the play will be trickier with more significant educational potentials. The game level design and planning various stages can be tested and execute throughout the game development life-cycle.

8 Conclusion

Games and simulations have been a part of the learning process in some form or another as long as records have been kept. They are an excellent way to learn a skill when actual experience is not practical, possible, profitable, or sensible. Despite the great impact of video games on contemporary society such as violence or depression. Educational video games on other hand may be able to provide students with the motivation they lack and making them an excellent educational learning tool. In this paper an attempt has been made largely for Buddhist cave monuments with special reference to Ajanta. Moreover, such game design concepts can be also implemented in other various heritage monuments in India of various historical eras. However, it can be concluded that a successful video game can be defined as those that allow users to re-create themselves in new worlds while simultaneously providing opportunity for meaningful learning at the same time.

9 Future Work

The limitation of the current study is to offer a game design framework and level designing for pre-production planning towards sustaining Indian cultural heritage, specifically ancient Buddhist cave monuments as game premise. There are three main outlines for future work: firstly need to complete the graphical notations in order to create the diagrams for each phase including designing primary characters,

environment, props will appear in the game with a proper game map design. second, designing of the particular game concept using the methodology including graphical notations so that it can be implemented by a company or an organization using the resources created; and third, incorporate the possibility of using a tool to assist with the creation of the game.

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Optimizing Roti Making in Street Food Outlets: A Human Factors Perspective

Sayantika Saha, Enakshi Chakraborty, Sweety Bardhan, Surjani Chatterjee, Neepa Banerjee, and Shankarashis Mukherjee

Abstract Due to the ever-changing economic condition in the last three decades especially in urban and sub urban settings, women getting more and more involved in monetarily rewarding occupational activities, they find it difficult to devote enough time for cooking. Often hence, food is purchased from outside with the mobile apps or from the neighbourhood vendors. Roti, a flat round South Asian bread, is one such very common food that is purchased and consumed by many Bengalee households as it provides the advantage of being rich in fibres and also low in cost. But nothing comes free, its making is a little more energy demanding compared to other cereal based foods like rice and like. Hence, there has been mushrooming of roti making and selling outlets in every neighbourhood in urban and sub urban areas in West Bengal. In this backdrop, a study has been undertaken in different south Bengal districts on roti making including the maintenance of hygiene and sanitation in outlets, with a view to analyse the time motion components in the process to finally suggest a suitable method so as to reduce the ineffective time, if any. The components have been found out, compared and a process prototype has been proposed in order to reduce the ineffective time as far as possible reasonably in order to make the units more economically viable.

Keywords Street food · Ineffective time · Time motion study · Breakeven point · Hygiene · WASH

1 Introduction

Productivity has now become very important in today's world. High productivity refers to do work in the shortest possible time with the same expenditure of resources, without sacrificing quality. This has now become very important in today's world which is directly related to the economic progress of a country. Work study which

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is done to enhance productivity by eliminating non-value-added operations can be categorized into method study and work measurement. A part of method study is motion study, and work measurement is also called time study. Altogether time and motion study has been known as a highly effective productivity-increasing process [1].

In the early twentieth century, Frederick Taylor proposed that losses in industries happen not due to the insufficiency of materials, but because of the waste of human effort and proposed the Time Study method aiming to minimise the waste in human effort. This method was later extended by Frank Gilbreth and his wife Lilian Gilbreth, disciples of F. Taylor, by inventing Motion Study. These two methods became integrated and referred to as Time Motion Studies (TMS) [2]. These processes are very reliable, give appropriate information and have been recognized as a required method of business efficiency technique to improve task management in different types of manufacturing industries all over the world which has altered the way of work accomplished nowadays [3, 4].

According to British Standards Institute, time study or work measurement is defined as, the application of techniques designed to establish the time for a qualified worker to carry out a specific job at a defined level of performance. Motion study or method study is the systematic recording and critical examination of existing and proposed ways of doing work as a means of developing and applying easier and more effective methods and reducing costs [1]. Time study has been done by using stopwatch for measurement. The main objective of the motion study is to reduce unnecessary operations during the task to ensure the highest productivity. In the present work, time and motion study has been applied in the street food outlets for optimizing roti making.

Roti, an unleavened flatbread, is a primary food made at homes, street food outlets even restaurants in India. Whole wheat flour (atta) which is usually used to make rotis, derived from grinding the wheat [5] and being a whole-grain cereal, has a protecting role against many metabolic syndromes such as cardiovascular diseases and diabetes mellitus [6].

100 g of whole wheat flour contains 64.17 g carbohydrate, 10.57 g protein, 1.53 g fat and 1340 kJ energy. The phytochemicals present in 100 g whole wheat flour are 11.36 g dietary fibre, 13.98 mg total polyphenols and 284 μg total carotenoids [7]. As wheat flour has a wide range of dietary fibre and phytochemicals, so when consumed these impart great health benefits, and help to prevent the risk of chronic diseases [8]. So, it is not desirable to sieve whole wheat flour as this process can reduce the bran fraction and thereby reduce the dietary fibre and phytochemical content. The dietary fibre present in whole wheat flour helps to reduce carbohydrate breakdown and thus glucose absorption rate, hence preventing excess glucose storage within the body [5]. Chapati, being a staple food, is eaten by a majority of the population at least twice a day in rural areas and it is a healthy option of carbohydrate without altering the food habits in urban areas [5]. However, the preparation of roti involves various processes, which if done judiciously by the person can reduce effort and time both.

In this backdrop, an attempt has been made in the present study to apply time and motion study as a time-saving method for roti making using video analysis.

Together with ergonomics, this information can help to reduce the chapati making time in street food outlets and as well as increase the income of the vendors. All the available information from existing scientific literature as available in Google Scholar, ResearchGate and PubMed, regarding this have been made to put together.

2 Methodology

2.1 Field Study

A questionnaire was prepared, standardized and administered about the price of the roti, what type of flours were used regularly and hygiene and sanitation of the vendors. Data were collected from five street food outlets in North 24 Parganas, West Bengal. The roti making processes were carefully observed in all outlets. After that, the preparation of roti was recorded in each outlet.

2.2 Motion Study

The recorded videos were later marked as 'A', 'B', 'C', 'D' and 'E' in motion study. The videos were recorded to observe how the work had been done and to find out the best way to perform a task. After that, the whole task was split up into various elements by which flow process chart was prepared for motion study. This contains some graphical symbols which were originated by Gilbreth (Table 1).

2.3 Time Study

Videos were also analysed for time study by calculating the time taken by each element to find out the ineffective time of work among these vendors which could be a reason of their less income.

3 Findings

1 average size roti in street food outlets weighs about 25 g and from 1 kilo whole wheat flour about 40 pieces roti can be made. The shops where gas ovens are used to make roti, the cost of 1 roti is Rs. 3/- and the shops where coal ovens are used, the cost of 1 roti is Rs. 2.5/-.

Table 1 The descriptions of various symbols used in flow process chart

Symbol	Name	Description
	Operation	Any action for making, altering or changing the characteristics of the material, for e.g., cutting of wood for furniture making, vegetable chopping, lifting, loading etc.
	Inspection	This represents examining and comparing an item with standard for quality and quantity, for e.g., visual observation for finish, counting the quantity of incoming material etc.
	Transportation	This represents the travel or movement of workers, equipment or materials from one location to another, for e.g., movement of materials to shops from stores, travelling of workers to bring something etc.
	Delay	This means the work has interrupted due to some reason i.e., a delay occurs when a next planned performance could not take place, for e.g., waiting of workers between consecutive operations, power failure, waiting for the instructions from supervisor etc.
	Storage	It refers to the stage of finished goods to an authorised area where they are placed more or less permanently, for e.g., a finished material in a stored room to be distributed later on

3.1 Motion Study

In motion study various recording techniques are used to simplify and standardise the recorded work. Efficient task management method is necessary for all types of industry and it has now become a competition to produce more with low cost and secure benefits. To achieve this, task management should improve first, and motion study can analyse this.

The main aim of this work is to eliminate unnecessary actions as well as to accomplish the best method of roti making to achieve highest productivity in street food outlets.

3.1.1 Flow Process Chart

The following table shows the flow process chart with symbols describes the process of making roti (Table 2).

3.2 Time Study

Time study was done on the process of roti making and analysed by using MS Excel and the comparison of all the result is shown in Table 3.

From the above table, it can be seen that the average total time for making one piece of roti is 120.8 s. If we eliminate the unnecessary operations, then the average

Table 2 Flow process chart of roti making

No.	Symbols	Process description
1		Make lump from the dough, rolling it into a round ball and flatten a little
2		Dust the dough ball with some wheat flour, rolling out to shape it round
3		Lift the roti from rolling board and place it on tawa
4		Roast the roti a little from beneath
5		Flip the roti and roasting the other side until gets little brown spot
6		On appearing little brown spot, roast the roti directly on the flame
7		Flip the roti very carefully to roast it
8		Take off the roti from the flame
9		Place on an airtight container

time will be 99.1 s. The first vendor named video A did not have any helper and took much more time though cooked on a gas oven, but the third vendor named video C also did not have a helper, took much less time and cooked on a coal oven. In the second video, named B, the vendor and his helper make many rotis at a time and they did not have any unnecessary operation because many elements were going on simultaneously, and take significantly ($P < 0.05$) minimum time for completion of the process compared to others. Other vendors i.e., video D and E also have helpers but they made one roti at a time on gas and coal oven respectively. Hygiene and sanitation related information like whether the vendors clean/wash hands with soap and water before commencing work and every time after touching food or using toilet, whether they use gloves or aprons and cover mouth while at work, whether they restrain themselves from eating, chewing, smoking, spitting and nose blowing within the premises, whether they take proper dressing measures for their cuts and wounds, if any, and like were collected as per the FSSAI standard guidelines of personal hygiene of food handlers [9].

Table 3 Comparison of the data obtained from time motion study

No.	Process	Time in seconds					Avg. time in seconds
		A	B	C	D	E	
1	Make lump from the dough, roll the it into a round ball and flatten a little	4	3	3	3	4	3.4
2	Dust the dough ball with some wheat flour, roll out the dough ball	46	18	19	22	21	25.2
3	Lift the roti from rolling board, place it on tawa	1	3	1	2	3	2
4	Roast the roti a little from beneath	57	17	23	39	21	31.5
5	Flip the roti and let the other side roast until gets little brown spot	38	17	11	14	9	17.8
6	On appearing little brown spot, roast the roti directly on the flame, Flip the roti very carefully to roast it	14	17	6	42	12	18.2
7	Take off from the flame, Place the roti on an airtight container	1	1	1	1	1	1
Total time by the summation of all process		161	76	64	123	71	99.1
Total time when overall work is done		215	76	70	130	113	120.8

4 Discussion

From the above result, it can be clearly seen that vendors who have coal oven, require less time for making one roti. It can be because coal ovens produced quick and high heat which make the rotis in less time, and reduce the production cost too. All vendors in this study used whole wheat flour, bought from mill. It has been reported that the high levels of protective components in the germ and bran of the whole wheat flour get reduced during the sieving process [10]. In Indian homes, atta is used for making roti after sieving, so most of the dietary fibre had been lost. But in street food outlets, they do not sieve whole wheat flour to increase the profit. As a reason for this, total dietary fibre is retained and makes the chapati useful for

our body in different aspects. Though all the vendors made the dough from their houses, but in all of these outlets', water is a major issue as there is no clean water source. As nutrition and water, sanitation and hygiene (WASH) are intricately linked, any food preparation workplace should focus on this aspect for better occupational environment, be it a formal or informal sector and ensure implementation of clean and safe living strategies ultimately leading to a safe and healthy population of India, a goal yet to achieve after 75th year of Independence. More in-depth study along with simulation is required for design intervention.

5 Conclusion

From the present study it may be concluded that the average total time for making one piece of roti is 120.8 s. If the unnecessary operations are eliminated, the average time will be 99.1 s. The first vendor named video A did not have any helper and took much more time though cooked on a gas oven, but the third vendor named video C also did not have a helper, took much less time and cooked on a coal oven. In the second video, named B, the vendor and his helper make many rotis at a time and they did not have any unnecessary operation because many elements were going on simultaneously. Other vendors i.e., video D and E also have helpers but they made one roti at a time on gas and coal oven respectively. It may be mentioned that time and motion study is very convenient to identify the ineffective time which further allows the conservation of human resources. The application of the time and motion study is effective to identify non-value-added, waste time, and eliminate them from the production line, and increasing production capacity.

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A Peer-To-Peer Teaching Model for Enhancing the Accessibility to and Quality of Education of India

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Abstract The education system of a nation is a crucial deciding factor of its growth through human resource development, empowerment, and productivity. Yet, one of the many problems it faces is concerning a large group of students under the care of Non-Governmental Organisations (NGOs) which generally remains deprived of quality education. Although NGOs project their objectives highlighting their focus on education and growth of children under their care, a considerable difference between their words and works is often found to have a limiting impact on the attainment of quality education. In this paper, a service design is proposed with the objective of connecting the children under the care of NGOs to students of schools of the Mainstream Education System (MES) in a peer-to-peer teaching model for effective exchange of knowledge and resources towards enhancing quality education. The realisation that humans are social creatures who depend on community interaction for most of their activities is one of the pillars of our proposed model in an attempt to focus on the importance of the "human side" of the service which enables an equal flow of benefits and opportunities amongst all stakeholders. This model seeks to incentivize the students of schools of the MES to voluntarily take part in this system which would assign credit points for successful completion of the service. It is emphasized that, besides directly contributing to the enhancement of education, this model would also help students develop soft skills and provide service to society, thereby making this model attractive.

Keywords Education · Human factors · Peer to peer · Schooling · Learning model

1 Introduction

India's education system has come a long way, with many vast and significant changes to the age-old gurukul tradition but the underlying importance of it has remained the same, if not increased, acting like a key that enables the nation to achieve economic and social prosperity through proper human resource development, empowerment,

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and productivity. The Indian pedagogical system constitutes over 1.5 million schools and purveys education to over 260 million young minds every year [1]. Yet, despite being the second-largest education system in the world [2], it is still grappling with many deep-seated problems. With a population of over 1 billion, India's literacy rate is at 74.04% [3]. Although many initiatives have been taken to improve the accessibility of quality education, a large portion of particularly socially and economically backward Indians still have immense difficulties in gaining basic quality education [1]. This is a consequence of a nexus of problems, primarily narrowed down to poor implementation, negligence, and the mindset of low per capita income families, who would prefer their children to start working from an early age. The National Education Policy of India 2019 sheds light upon the fact that a large portion of the Indian population (estimated to be over 5 crores) have yet to attain foundational literacy and numeracy, despite the implementation of policies like the Sarva Shiksha Abhiyan and the Right of Children to Free and Compulsory Education. Even for the proportion of students who go through primary and secondary schooling, the quality of teaching widely differs depending on factors such as government-supported or fee-based schools, teacher-to-student ratios, etc. [4]. This makes the achievement of accessible quality education to every child, youth, and adult, in spite of social or economic barriers, a priority. Non-Governmental Organisations (NGOs) play a role at the grassroots level to adopt innovative and sustainable practices to strengthen the pedagogical system, increase awareness about its importance and ascertain the enrollment of as many children as possible so that the success of the urgent national mission of attaining quality foundational literacy and numeracy is achieved [5]. However, although NGOs project their objectives and activities highlighting the focus on education and overall growth of the children under their care, there are many factors that affect their services, consequently affecting the children negatively, such as lack of funding and wrongful spending of available funds to less prioritized directions due to corruption, lack of available resources and facilities for more than a threshold number of children [6], teacher absenteeism, and negligence of the children under their care by NGO officials.

Although the government has a significant role in imparting proper quality education to children, there is still a need for for sustainable and innovative models of teaching-learning systems.

NGOs have demonstrated that community reserves such as the abundant literate human resources lie largely unexploited [7] and should be gainfully employed in voluntary activities that could help in problems such as teacher absenteeism and low teacher-to-student ratios. Contribution by and collaboration between the voluntary and private sectors as well as communities and a collective approach in the design process of any service by involving each and every stakeholder, be it in the education sector or any other industry, is important for the said sector's success [8]. This will not only strengthen the bridge between the various spectrum of people in the community that leads to a decline in the number of educationally backward individuals but also makes the efforts of the government to actualize the goal of universal elementary education easier to achieve [7]. One such activity that could be voluntarily taken up is peer teaching [9], which would enable the literate population of India,

which is in majority, to educate those who face socio-economic barriers to attaining literacy, thereby resulting in an increase in the literacy rate. The peer-to-peer model of teaching-learning is based on the realization that students feel more comfortable learning from their peers, enhancing the effective exchange of knowledge. The peer-led education approach is an effective behavior change strategy, increasing the power of thought, creativity, participation [8]. A study by Stanford University pegs this aspect of the learning process as pivotal to students' ability to study better, retain information, and attain academic excellence [10].

According to an article by McKinsey and Company, in order for a service to succeed, one needs to take into consideration its "human side". This side refers to the factors that need to be taken into consideration in order for the service to be human-centric and usable by the targeted stakeholders. These factors can vary from one service to next, yet the basic underlying foundation to be kept in mind is the same—making it user centric, co-creative and adaptable with a properly established purpose that solves a concrete, real-life problem that the targeted and potential users of the service are facing [8].

The objective of this paper is to propose a pedagogical model that relies on partnerships between schools of the Mainstream Education System (MES) and NGOs in a human-centered, peer-to-peer teaching model for effective exchange of knowledge and resources towards enhancing the accessibility to and quality of education. The presence of the above-mentioned factors will be highlighted across the paper in order to demonstrate the presence of human factors in the prospective service.

2 Literature Review

In India, peer education is the government's primary approach for bringing about behavior change among high-risk groups in the context of sexual and reproductive health who are susceptible to SRH complications [11]. It has been introduced in the field of sexual and reproductive health (SRH) as an intervention for promoting the SRH of people. A peer-based model was developed in 2005 to educate and empower low-literacy communities in the rural district of Perambalur about sexually transmitted diseases, primarily HIV [12]. The main objectives of the program were to disseminate awareness within the community, empower its people through participatory peer training and teaching, and creating safe spaces for a healthy exchange of knowledge and support. The system involved the collaboration between various socially established NGOs, women's self-help groups, barbers, and other voluntary members of the community in training peer educators and conducting informative sessions to spread awareness. The results of this peer training program came out on a positive note. An overall increase in the ease of exchange of knowledge between the peer educators and the general public was observed along with a drastic change in attitudes and risk behaviors. This case study casts light on the promising impact of peer education on training and empowerment of people with little or no

academic credentials and consequently bringing about social upliftment. It demonstrates the requirement of garnering the unrecognized community resources to bring about similar conclusive changes in other aspects of social development, including the accessibility of quality education and resources for attaining quality foundational literacy and numeracy. Being a communitarian model, peer education provides an opportunity to sustainably facilitate pertinent developmental information at relatively low costs.

Another program was introduced through the Adolescent Reproductive Health Strategy (ARSH) and the subsequent National Adolescent Health Programme, or Rashtriya Kishor Swasthya Karyakram (RKSK) in 2017 with the vision to "increase accessibility and quality of information, counseling, and services, to ensure that adolescents can realize their full potential by making informed decisions related to their nutrition, mental health, and SRH" [12]. The recognized benefits of this model were its ability to uplift society by empowering adolescents to create a healthy environment of knowledge exchange amongst themselves, helping out-of-school children in acknowledging problems related to SRH, and creating safe friendship networks [13].

The theoretical support for peer education comes from the theory of participatory learning is based on both behaviorism as well as cognitive and social psychology. In the Participatory Learning Approach (PLA), students actively take part in the learning process. It can help the student view problems from different perspectives [14] facilitating a broader understanding of topics. PLA also encourages collaborative learning, ensuring that there is respect, understanding, and collaboration between the students.

3 Methodology

The theoretical basis for our peer education program comes from a process-oriented approach introduced by Rothman and Tropman in 1987 whereby a synergetic environment is created within the community so as to establish people's participation [15] in the form of a macro intervention. The macro intervention in this approach focuses on systems such as organizations, communities, and regional and national entities [9]. Our system follows the Locality Developmental Model proposed by Jack Rothman in 1996 that focuses on broader participation from the community. The key concepts of our model that we aim to include are increased empowerment of the community through participatory peer training and teaching to facilitate a healthy and quality exchange of educational information and resources.

3.1 Identification of the Key Stakeholders for the Peer Education Model

Identifying the stakeholders who would take part in our service is an important human factor that needs to be considered to enable them to design and deliver the service co-creatively and facilitate an equal flow of benefits and opportunities amongst all stakeholders. As stated in the introduction, according to many governmental and non-governmental surveys, around 5 million children do not have the access to quality education even for attaining foundational literacy and numeracy [9]. This makes educating those children a priority in order to surmount this critical barrier. Therefore, one of the principal stakeholders in our bilateral knowledge exchange model would be those who are at the elementary level of learning from preparatory to middle school education, following the new pedagogical structure envisaged by the NEP 2020 [9].

The other principal stakeholder of our model is the students of schools of the MES who would be the peer educators responsible for catering to the necessities of the children in need of quality education and resources. These children would primarily be those who are at the secondary level of the pedagogical structure [16].

Secondary stakeholders include the administration of the schools of the MES and of the NGOs who are responsible for the educationally disadvantaged children. Both of these administrative bodies would appoint one representative each who would oversee that the bilateral exchange of knowledge between the two principal stakeholders is successful.

Tertiary stakeholders comprise the government, the local governing bodies, and Asha and Anganwadi workers (AAWs) who will be responsible for the collection of data related to the individuals of the area under their jurisdiction who are in need of quality elementary education.

3.2 Carrying Out a Needs Assessment

After the identification of key stakeholders, a needs assessment of the children was carried out using both quantitative and qualitative methodologies. The quantitative methodology used was the conduction of a survey and the qualitative methodology used was focused on group interviews. These allowed us to determine the direction and scope of our model. By taking into account user input, the designers will be able to create the service in such a way that it caters perfectly to the user needs.

Conduction of survey: The survey was targeted towards children belonging to the elementary level of learning from preparatory to middle school education to focus on the direction of the project and conduct a needs assessment. This survey consisted of questions related to whether children find it feasible to approach their friends for discussions to teach and learn from each other. The questionnaire started with asking the children how often they discuss their lessons with their friends. Out of the

Fig. 1 How often students discuss lessons

respondents, 56.3% of children discuss their lessons sometimes, 25% discuss often and 15.6% discuss always (see Fig. 1).

The next question asked the children to rate their level of comfort with asking their peers for help in their studies (see Fig. 2).

The majority of the students felt that asking for help from their peers would not be out of their comfort zone. The students were then asked the time period during which they had peer discussions. Over 40% of students preferred to study with friends during exam season. Stressful and important academic periods become easier when children do it in groups as they have a way for encouragement and de-stressing in a supportive environment (see Fig. 3).

According to 40% of the respondents, these discussions helped them in understanding their lessons considerably better (see Fig. 4).

The students were then asked whether they approach their friends to explain concepts or help them solve questions. This question was asked to determine whether students willingly take part in peer study activities. The survey showed that 96.8% do approach their friends (see Fig. 5).

80.6% of students felt that teaching others helped them understand a concept much better than studying alone (see Fig. 6).

Lastly, the students were asked the number of people that they preferred to be in each peer study session. This was asked in order for us to determine the structure of our peer study model. The majority of them preferred a maximum of two more friends with them in one group for easy discussions (see Fig. 7).

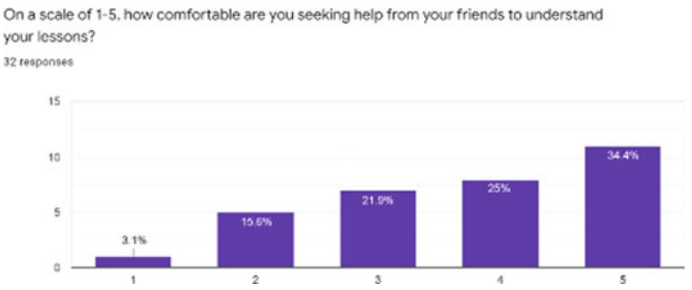


Fig. 2 How comfortable children are with seeking academic help from friends

Fig. 3 When children discuss their lessons with their friends

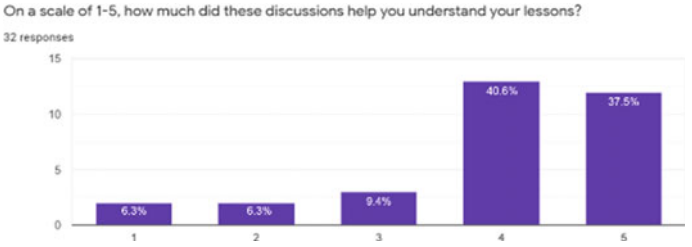
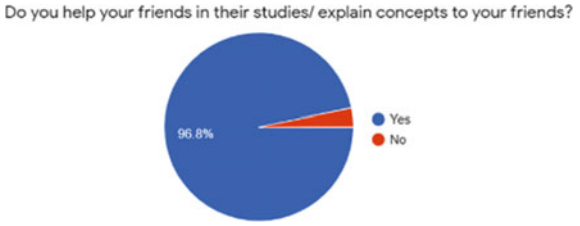


Fig. 4 How much group discussions help children understand their lessons

Fig. 5 Whether children help their friends understand concepts



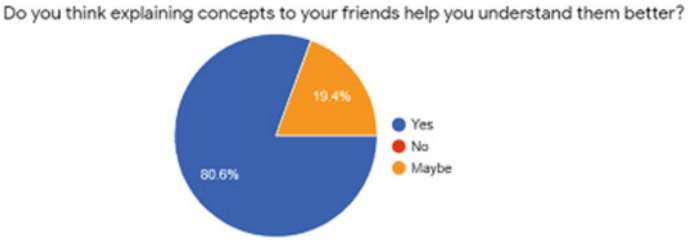


Fig. 6 Does explaining concepts to friends help students understand them better

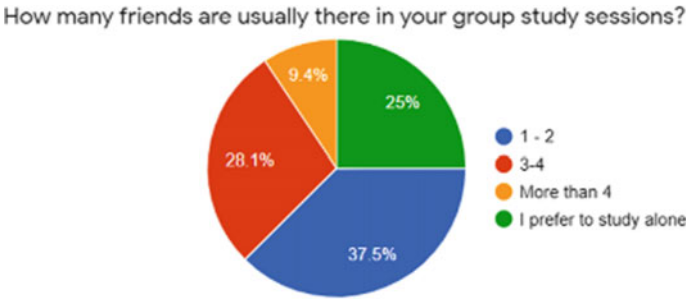


Fig. 7 Number of students in a group study session

This survey elucidates the importance of peer discussions and study groups in the educational journey of a student. To further the extent of acceptability of this intervention by other key stakeholders, it was decided to hold focus group interviews, the details of which are presented as follows.

Interview Insights: Interviews were taken from established school teachers, psychologists, and municipal officers in the form of focused group discussions (see Table 1). These discussions revealed how there is a need for an efficient and innovative intervention in this field in order to make it more inclusive, acceptable, and beneficial to all stakeholders.

3.3 Proposed Model

The proposed model, named the Chhatra Pragati Yojna (CPY), is designed to facilitate peer-to-peer education through the participation of a broad cross-section of the community members, the paramount objective being direct intervention at the grassroots level. Our model aims to connect the children under the care of NGOs to students of schools of the Mainstream Education System (MES) in a peer-to-peer teaching model through the creation of a collaborative environment between the schools and NGOs. The entire system is conveniently forked into levels, each level having its individual duties, which when fulfilled leads to a successful conclusion (See Fig. 8).

Creating awareness and increasing accessibility: AAWs are major pillars of communal health in both rural and urban parts of India. At present they are responsible for the promotion of reproductive health services and antenatal and postnatal care of women and children. Anganwadi workers carry out a survey of all the families and organise non-formal pre-school activities in the Anganwadi of children in the age group 3–6 years of age. In the context of our system, with a few additions, the already established system of AAWs can provide immense benefit, with their present capacity this community resource can help create awareness, encourage children to enroll in

Table 1 Interview insights

S. No.	Interviewee	Response	Inference
1	Primary school teacher	"Children coming from poor backgrounds do not receive quality education, & those who do have low quality & quantity of faculty and resources"	This insight brings to notice the disconcerting pedagogical state of our country that caters to the needs of socio-economically disadvantaged groups
2	School Principal	"A major problem is that not only does India suffer from poor quality teachers, it also has fewer total teachers."	A high student–teacher ratio in understaffed schools poses a complication to a child's learning as the students do not get the required amount of attention that is essential in order for their full potential to be recognized
3	Parents of a student studying in 8th standard	"Education in most schools is dictated by standardized tests and mere numbers."	The teaching structure of India is still very facile in terms of its success metrics, which focus on marks obtained in periodic theoretical tests more inclined towards rote learning than actual understanding of concepts. There is an urgent requirement in teaching methods that would allow students to develop practical and soft skills along with theoretical ones
4	An officer from the municipality	"Instead of giving away things for free such as tablets or laptops to those whose primary requirement is not these materialistic things but is basic quality education, the focus should be more on coming up with innovative approaches to tackling problems like teacher absenteeism, ignorance, and lack of educational opportunities."	Many government schemes exist that give away free products. Albeit these have their own significance and importance towards accessibility of resources and opportunities, an increase in focus on providing basic education could result in optimum utilization of these products as students would then be able to make use of these in their educational requirements more

Fig. 8 System map of Chhatra Pragati Yojana

this program, and reach every corner of the community, effectively increasing the accessibility to education. AAWs collect the demographic data including age, gender, education status and financial status. Further, developing close relations with each family within their regions, and assuring them of the benefits of education, builds trust and reliability of the service.

Data collection and Analysis: The demographic data collected by the AAWs would then be provided to the local governing body of the area under their jurisdiction who would further analyse the same. Under our system, the data that would be scrutinized is related to the number of individuals who remain unschooled or those who have dropped out previously from school. This particular collection of data would help to familiarise the AAWs with the situation of their area and further take actions, which are demonstrated in the following section.

Enrolling in the scheme: The AAWs would be responsible to get in contact with the concerned families and motivate them to join the nearest NGO to their residence which is registered with the CPY scheme. Further, NGOs will be responsible to register the children into a registered open-schooling board such as National Institute of Open Schooling. All stakeholders will be connected virtually to each other through the CPY digital portal, which will allow schools and NGOs who are interested in the scheme to register themselves as willing participants for this bilateral knowledge exchange system. The Digital Portal will keep a database of all the schools and NGOs and the number of students each is dealing with, all statistical data will be public and each stakeholder will be accountable for their duties. Through enlistment on the CPY portal, schools will get the benefit of being accredited by school accreditation boards such as the National Accreditation Board of Education and Training, thereby increasing their rankings. After successful enrollment in the scheme, the portal would connect NGOs with the nearest registered school. Following this, both parties would discuss and agree upon the discussion settings, timings as well as the appropriate curriculum to be followed in order for the children on both sides to reap benefits.

Selection, training, and appointment of the contributors to the program: At this stage, teachers are selected by the school administration to supervise and provide necessary support for the smooth educational exchange between the peers. The school gives an opportunity to the children to volunteer on the basis of their subject preferences and a skill-checklist provided to them, as per the prescribed curriculum and agreed upon schedule. Students would then be selected on the basis of their behavior, co-curriculars, attitude towards their teachers and peers, class participation and overall assessment. Students are incentivized to take part in this system through the provision of additional grade points, boosting their overall academic

result, personal development and an opportunity for community service which is a desirable skill for higher education and future employment opportunities. On the NGO's side, a representative would be selected on a voluntary basis who would assist the teacher supervisor in making sure that the system runs successfully.

Setting up a discussion environment: The NGO sets up infrastructure for the sessions. The discussion spaces that are to be used would be discussed between the schools and NGOs on being connected through the portal. The spaces used could be public spaces such as parks and auditoriums, for a better and holistic learning experience. To make sure that the pedagogical exchange and comprehension between peer groups is optimized, the children under the care of NGOs are divided into groups with a maximum of four members. Two peer educators from schools of the MES are appointed to each group. Teaching is conducted in the form of discussions and debates such that a healthy learning environment is created. Appointment of the number of selected teacher and NGO representatives would be on the basis of the number of peer groups per session. The study hours to be dedicated by both peer groups in order to ensure successful dissemination of quality education shall be decided based on the curriculum to be followed.

Monitoring and evaluation of the system: The system will be monitored on a regular basis through random inspections which will be conducted not less than four times a year. Children under the care of the NGOs would be enrolled in an established open schooling board. This would allow them to appear for certified examinations on the basis of the knowledge gained during the entire session of the CPY peer education program. The students from schools of MES who volunteer and take part in this system would get assigned credit points for successful completion of their responsibilities.

4 Discussion

This paper highlights the challenges faced by the Indian education system, especially in delivering basic foundational literacy and numeracy and proposes the development and implementation of a human-centric model following the novel yet customary learning framework of peer-to-peer education. Since the service guarantees that all stakeholders get the information needed to make well-informed decisions, it can be implied that the service follows a human-centric approach to solving the highlighted problem. The adaptability of the service is a salient indicator of how user centric the service is. The ability of our proposed service design model to be implemented in multiple case scenarios and special cases is an achievable goal that reinforces robustness and makes it resilient. This is possible through the structured and punctual collection and storage of data by the administration portion of the stakeholders such as AAWs and the local governing bodies. The proposal of this model was discussed with professionals from fields such as education and psychology and insights were

gathered to validate the model. Chhatr Pragati Yojana, as told by a practicing psychologist, can ensure effective learning, as there is affinity and understanding between peers of similar ages. Children can easily get acquainted with their peers, owing to a low age difference, as compared to teachers much older than they are who will hold an upper hand on the children. This comes from the theory which states that effective exchange of knowledge can take place when there is no subordinate-superior relationship and the interacting individuals have coordination and equal footing [13]. The involvement of individuals belonging to the socio-economically weaker sections of the population makes this system an inclusive initiative that works towards their empowerment and social upliftment. An insight given by a professor in the educational field emphasises that, besides directly contributing to the enhancement of education, this model would also indirectly help students to develop their soft skills along with social, emotional and ethical development and get a feeling of satisfaction of giving service to the society, thereby making this model attractive. According to a primary school teacher, this model has the potential to surmount the problem of teacher absenteeism and high pupil-teacher ratio, which would help in the realisation of the true potential of each and every student through increased individual attention.

5 Conclusion

Even though the Indian pedagogical system is the second largest in the world, there are many profound complications that are faced, one of them being the challenge concerning the children who are under the care of NGOs, the attainment of quality education of whom largely gets affected by issues pertaining to factors such as lack of funding and wrongful spending of available funds to less prioritized directions due to corruption, lack of available resources, etc. Using the concepts of collective participation of the community in the form of peer-to-peer interaction which connects the children under the care of NGOs to students of schools of the Mainstream Education System (MES) in order to facilitate effective exchange of knowledge and resources to improve the accessibility to and quality of education in India. The proposed framework aims at uplifting the conditions of individuals belonging to socio-economically disadvantageous backgrounds with little to no access to foundational literacy numeracy through an equal exchange of education and skills amongst the two peer groups and encourage a healthy, harmonious and productive environment. Through discussions with established professionals in fields like education and psychology, it has been ensured that, through the Chatra Pragati Yojana scheme, a positive change can be brought about. This model gives an opportunity to the Indian government to make education accessible to all, thereby increasing the country's literacy rate.

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Exploring Aesthetics of Vaastu Shastra: Transformation of Domestic Architectural Spaces

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Abstract Vaastu Shastra is considered an Ancient science that stemmed from the way of life aligned with nature. Design that connects with man, nature, and its science deals with a more systematic and user-friendly interface, the resultant space ensures user well-being within the guidelines stipulated by Vaastu Principles. To a particular extent, principles of vaastu shastra lead the design process, which tries to extend its application throughout the evolution and transformation of the built environment. The aesthetics of the built environment, as per Vaastu Shastra are maintaining its historical trajectory and preserving its design sense in continuity. Nevertheless, domestic architectural spaces are susceptible to changes over time-based on design requirements and advancements in construction techniques. Thus the connection between a User oriented space and the environment connect seems to be missing. The relationship between the environment and human interactions fetch an extra value to traditional architecture. The fundamental pramanas (principles) of Indian vaastu ensure the quality of both life and built environment in any dynamic circumstances. The current study evaluates the environmental aesthetics of traditional domestic architecture through principles of vaastu and usability heuristics by exploring 2 different architectural case studies from pre-independence and modern times.

Keywords Vaastu shastra · Principles of vaastu shastra · Traditional architecture · Domestic architecture · Environmental aesthetics · Usability heuristic

1 Introduction

People live and dwell within a variety of constructed and unconstructed environments and showcase the harmonious relationship between man and nature. Traditional architecture evolved reveals the aesthetic integration of the built space with the

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surrounding context. The Aesthetics of traditional architecture narrates not just the present context but also describes the historical identities imbibed in it to address the transformation over time. The assessment of the built environment and its functionality, safety, and aesthetics are often automatic and influences the daily needs, and is linked with the ergonomic and technical quality of a space, thus imparts the final impression of aesthetics [1]. Aesthetics in built environments are hard to evaluate as it based on perception. The aesthetic qualities of domestic architecture adhere to the building science from its vaastu shastra origin from ancient times, provides order in the production of spaces, and can be evaluated on shared meanings of spaces resulting from culture and tradition. The traditional built environment, which evolved under the guidelines of vaastu provides sequential spatial order in the composition of space. Culture influences the way people think and use a space; it impacts the preferences and choices of dwelling features [2]. While discussing the relation of humans, the environment, and their dwellings, one could understand the human culture from history to contemporary lifestyle. Vaastu Shastra's practice in built spaces is gaining importance because of the flexibility of such science to adapt to the changing needs, supporting a way of life in alignment with man and nature. In the contemporary design world, vaasu shastra is gaining a superstitious outlook as is misinterpreted to accommodate modern lifestyles as well as unauthorized practices in the name of faith. A meaningful interpretation of vaastu shastra away from superstitious beliefs is required to utilize the adaptability of vaastu shastra practice in domestic architectural spaces as it is susceptible to drastic changes because of the changing need according to time.

2 Vaastu Shastra

Vaastu Shastra is an ancient knowledge of both art and science, formulated and used from prehistoric times. The origin of vaastu shastra can be traced back more than 2000 years. Vaastu shastra is an upaveda (sub domain of Indian system of knowledge"veda") [3]. Vaastu shastra is based on the balanced composition of pancha bhutas (The five basic elements of nature including water, fire, air, sky, and earth). According to the trinities of vaastu, it is believed that these elements could influence on location, direction, and even on the construction which directly impacts human life. Hence the main concept of Vaastu shastra reveals the relation shared between the human, building, and the universe. A renowned vaastu researcher, Patra [4], identifies humans as a subject, object, and a cause of vaastu design. Thus vaastu is an ancient principle of human factors in India, which is an applied science and philosophy of construction, it can be easily adaptable, extensible, and upgraded to match the needs of modern lifestyles and materials.

2.1 Principles of Vaastu Shastra

The principles of Vaastu Shastra acts as the basis for guidelines and rules to mold the built environment [5, pp. 776]. There are seven basic architectural principles in which Vaastu Shasta considerations in design can be applied;

1. Examination and selection of site; Bhupariksha
2. Determining the Orientation; Dik Nirnaya
3. Building measurement test; Aayadi Gananam
4. Vaastu Purusha Mnadala; Padavinyasa
5. Zoning;Griha Vinyasa/ Sthana Vinyasa
6. Door Openings;Dwara Sthana
7. Proportion of the building;Bhulamba Vidhanam [6, pp. 54].

2.2 Domestic Architectural Development of Kerala; Grhavaastu

Kerala is situated in between the Natural barriers formed by theWestern Ghats and the Arabian Sea. There haven't been any foreign invasions ad subjugation, thus presents a perfect background for studying the evolution of Architecture [7]. The architecture of Kerala influenced by Dravidian and Indian Vedic architectural science over a period of two millennia. Up on different texts on Vaastu Shastra, namely Agamas of the twelfth century BCE, Manasara sixth century CE, Mayamatam of the ninth century CE, Silparatna of sixteenth century CE, and Manushyalaya Chandrika of sixteenth century CE contributed to South Indian Architecture [6, pp. 53]. Traditional Architecture of Kerala has two major streams, Temple Architecture (Kshetra VaastuShilyi) and Domestic Architecture (Manushyalaya Vaastu Shilyi). Manushyalaya Chandrika, a work devoted to domestic architecture, has its strong roots in Kerala.

The Domestic Architectural space evolved reflects the culture, belief, and tradition of that region. Traditional Architecture of Kerala follows the principles of Vaastu Shastra and is derived through an applied science approach considering the socio-cultural needs and climatic aspects. The environment that leads to the inception of early domestic Architectural spaces is no longer the same and has undergone drastic changes considering the social scenario, cultural needs, material availability, and climatic context. The introduction of new materials and technology led to changes in Domestic Architecture after the mid-twentieth century.

2.3 Grhavaastu and Human Factors

As Le Corbusier stated, house is a machine for living in, it supports daily life and activities; hence built space interaction with man, the environment, and its traditional

trajectory are essential to be analyzed for the benefit to the society. Vaastu shastra evolved considers humans as the centre and leading causes of its principles. The domestic architecture evolved through the ancient building science system like vaastu shatra, ensures ease of work, User's comfort, and safety. The relationship between aesthetics, ethics, and the traditional research issues of human factors are important and beneficial to human society [8]. Hence, the role of aesthetics in human factors or ergonomics is to be explored to understand the importance of vaastu shastra science in contemporary times.

3 Methodology

This research paper intends to investigate case studies from the ancient period as well as modern domestic architecture. For illustrative purposes, only two dwellings from two different Periods of the domestic architectural evolution are taken from Kerala. The research method chosen is case studies and combined strategies, and it aims to explore environmental aesthetics. As per environment psychology, whatever embraces mankind and their spiritual and physical existence is called the environment [9]. The study follows a subjective assessment method for evaluating the aesthetical quality of built environments, shared meanings of an architectural space and cultural values attached to the space through a vaastu point of view. Vaastu Shastra outlines a theory of environment design based upon person-place identity[10]. Aesthetic quality attached to a space can be evaluated based on various methods including generalizing public opinions or analysing aesthetic experience of users [11]. According to Sardhari and Rashidi (2017), the aesthetic evaluation can be done in 3 different ways (see Fig. 1), symbolic, former, and sensory. However this study explores the former aesthetic evaluation of the built environment through a vaastu point of view.

User perspective as well as professional interpretation in connection with usability and environmental aesthetics are to be explored for suggesting corrections for the vaastu principle application in contemporary dwellings. Heuristic evaluation is one

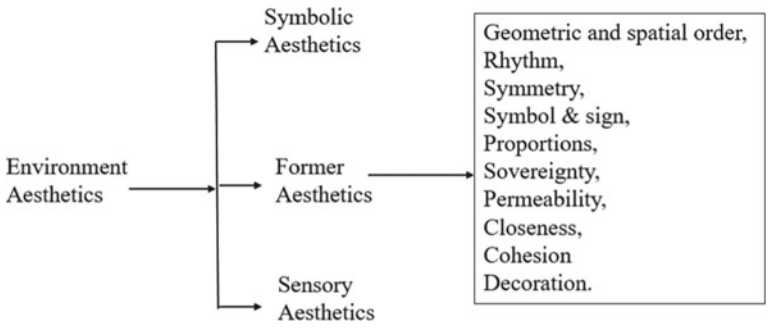

Fig. 1 Former aesthetics variables Sardhari and Rashidi (2017)

of the most commonly used usability inspection methods. According to Nielsen 1994, usability heuristics plays a key role in the performance of a system [12]. Moreover, researchers identified basic ten heuristics [13]. Nielsen and collaborators used this method for evaluating human computer interface performance. Here in the current study uses the heuristic evaluation method to assess the aesthetical and ergonomic quality of the built environment [14] in a vaastu point of view. Usability heuristic evaluation is carried over from all the stakeholders of vaastu including users and practitioners such as design professionals and students. The study allowed the evaluators to have an open discussion and brainstorming on the topic, meanwhile the researcher took notes and documents these interactions as moderator. Finally inference has been drawn on the basis of these stakeholder interactions and ancient vaastu texts.

4 Results and Discussion

For illustrative purpose, two case studies taken for the investigation is as follows; *Case-1*; Varikassery Mana is situated in Ottapalm, Palakkad District in Kerala. The Mana/house construction dates back to more than 130 years. This Nalukettu house is designed according to Vaastu Shastra principles by Valanezhi Jathavedan Namboodirippad. In 1902, Krishnan Namboothiripad given a design for the Poomukham adhering to Vaastu Shastra, after no other addition to the original construction is done, and the present use of the Mana serves as a tourist place portraying the traditional domestic architecture. The space requirement of the house is for the joint family system. There are four blocks in the house around a central courtyard space. Vadakkini (Northern block) accommodates Pooja room, Kitchen, and sacred spaces. Thekkini (Southern block) accommodates bedrooms and sleeping places. Kizhakkeni (Eastern block) accommodates Entrance halls, drawing halls, and guest rooms. Padinjathenni accommodates (Western Block) Granary and storerooms.

Case- 2; Contemporary Residence for Mr. & Mrs. Joshi at Thrissur District, Kerala. The Modern Nalukettu house incorporates Vaastu Shastra principles and was constructed in the year 2016. The entrance hall is at the Eastside; the Southern block accommodates Kitchen and Pooja rooms. The house is built as per the design directions from Vaastu Acharya.

4.1 Principle 1-Examination and Selection of Site; Bhupariksha

Bhupariksha gives guidelines for the selection of site before construction. The Shape, contour, color, texture, odor, features, taste and touch are to be tested to ensure the suitability of soil for construction purposes [5, pp. 776, 6, pp. 55]. There was a

possibility to go for Examination of site before construction in Varikkassery Mana. But in Case-2, because of the plot restrictions issues that exist today, the option of checking the site was not available. To overcome the restrictions of the poor soil conditions, the soil can now be tested in a more scientific method [15]. The criterion in use today are the shape of the site, contour, and adjacent roads. Currently, the five senses that elicit site selection are absent, reducing physiological comfort in the produced spaces.

4.2 Principle 2-Determining the Orientation; Dik Nirnaya

In Case1, the space allocation given as per vaastu shastra Guidelines. The north block accommodates Kitchen, Pooja rooms, and sacred spaces. The entrance to the house is from the Westside. In Case-2 the entrance is from the Eastside. Granary space is not provided in Modern style residences as it is not the need of the present lifestyle and context. In both cases, the main spaces aligned to cardinal directions, here the ordinal direction are avoided. The theory of orientation is secular and religious in nature, and they have applied it by maximizing the benefits of solar radiation [5, pp. 776]. The Principle of Determining 'orientation' is still in practice in a modern residences and it ensures ease of use and climatic comfort in an auspicious way in connection with tradition.

4.3 Principle 3-Building Measurement **T***est; Aayadi Gananam*

In case-1; The Measurement system is derived from the eldest member's anthropometric data of the house to ensure the efficacy of space utilization and taken using constructional rod 'kol'. The measurement system is according to the Hasta system, derived from the Human body. The spaces arranged considering the material specification and types of construction, and the resultant proportion serves as a fraction for all other dimensions. In vaastu shastra the reminder system is conceptualized to give continuity to spaces and function.

In Case-2; Modern residences, the proportions mentioned in the vaastu texts followed without considering the user dimensions and modern materials specifications. Modern materials like concrete, glass, etc., are not taken into consideration in design. Hence the vaastu shastra proportionate measurement system does not serve the full benefit. The correlation between the cosmos and micro cosmos established through mathematics, geometric forms, astronomical calculations, etc. The application and integration of time scale and the scale based upon human body proportions create resonance even at a subtle level [16]. The complexity and contradiction in the measurement system do not allow for a smooth and understandable application of

the measurement system in modern residences. Currently dwelling designs follows western anthropometric standards, thus does not ensures efficient utilization of space.

4.4 Principle 4-Vaastu Purusha Mandala;*Pada* Vinyasa

The vaastu Purusha mandala acts as regulating grid and guides spatial planning.

The Earth is conceived as a circle, but it is referred to as vaastu after it is oriented and rendered habitable. And it seen as a square fixed in the cardinal directions [3]. The square grids allow for flexibility in design without losing the symbolic meaning. The esoteric complexity of vaastu shastra has a magical appeal and theoretically roots the design in tradition whilst a visual label of modernity could be retained by limiting to a grid [17]. Vaastu Purusha Mandala, a generative idea [18], forms a guideline for imposing spatial planning and symbolic meaning. In domestic architecture, the 8 × 8 grid system is used to ensure continuity, and in both cases, as shown in Fig. 2, the 8 × 8 grid is provided. The grid system in design allows for a sequential order in designing spaces; thus a user-friendly interface is formed to enable consistency and ease of use.

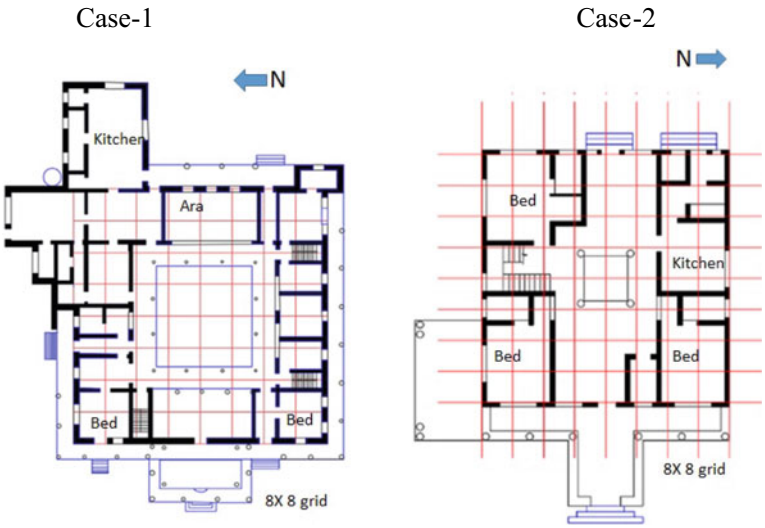

Fig. 2 Vaastu Purusha Mandala—case-1 (Varikkassery Mana) and case-2 (modern residence)

Table 1 Zoning; Case 1 (Varikkassery Mana) and Case-2 (modern residence)

Spaces	Orientation-case-1	Orientation-case-2	Preferred locations
Bedrooms	SW/NW	S/SE	S
Kitchen	NE	NE	SE/NE/NW
Living room	W/NW	E	W/NW
Dining room	W	W	W
Pooja room	NE	E	NE
Bath/toilet	NE/E	S/SW	NE/E
Storage space	SE	SE	SE

4.5 Principle 5-Zoning; Griha Vinyasa/Sthana Vinyasa

Zoning spaces and activities help in bringing proportions of different parts to the buildings. Zonings of various functional activities are allotted in the names of God in Vaastu Purusha Mandala [6, pp. 57]. The symbolic meanings are retained without compromising the modern design elements. Table 1 shows orientation of different functional spaces from both cases.

The spaces are zoned to take advantage of the climatic considerations. The transparency in zoning principles ensures its application in modern designs also. The zoning, as per vaastu holds the cultural value as well as provides physical comfort.

4.6 Principle 6-Door Openings; Dwara Sthana

The location of the main door located slightly away from the Middle axis of the building. Preferred auspicious, main door locations are from East and West. The traditional vaastu shastra belief states that two to three aligned openings along the same row can be avoided in design. In Case-1, unaligned door/window openings in a single row are given, but in the modern residence, aligned openings are provided. Not having two to three aligned openings in a single row, proven to be technically correct, and there is an engineering significance of it [19]. Un-aligned door openings accentuate the wind flow inside the building, and this consideration can apply in modern designs to impart the climatic comfort by utilizing the cross ventilation considerations.

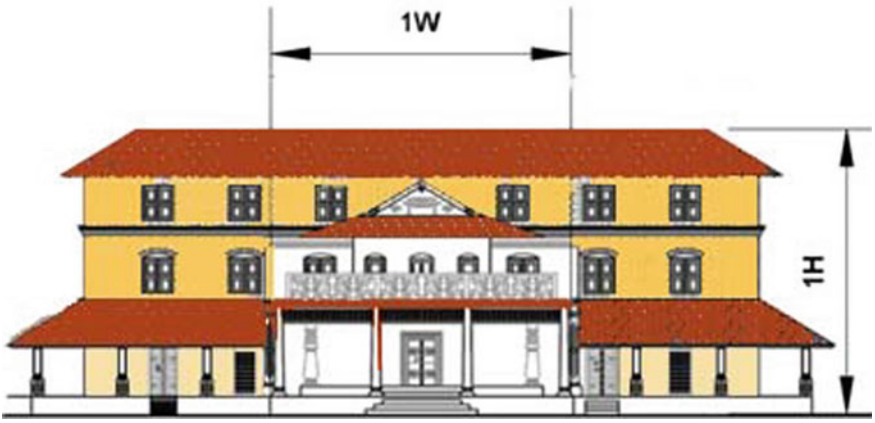

Fig. 3 Varikkassery Mana-1 W:1H Poomukham proportion

4.7 Principle 7-Proportion of the Building; *Bhulamba Vidhanam*

Length to breadth proportion to ratio is significant in providing the aesthetics of the building. There are five generic types of proportioning system as per Manasara and Mayamatam and is as follows; Shantika (1 W:1H), Paustika (1 W:1 ¼ H), Jayada (1w:1 ½ H), Dhanada (1 W:1 ¾ H) and Adbhuta (1 W:2H) [9, pp. 58]. In Varikkassery Mana, the main attractive feature is the Poomukham area. The proportion of the Poomukham was found to be 1 W:1H, as shown in Fig. 3. In modern residences, the proportion is not confirming to any of the Vaastu Proportioning systems. In Indian tradition, beauty is considered as Chanda (moon), the structural marvel, and its rhythmic disposition is conceptualized like that of a poetry [20]. The aesthetic considerations in design are considered to be very important and is matched with human proportions to enhance the user experience and acceptability.

5 Environmental Aesthetics in Domestic Architecture

The transformation of domestic architectural space accounts for many deviations from vaastu shstra Principles. Environmental former aesthetics are explored along with the transformation of spaces to identify the drastic changes affecting the aesthetics. Usability heuristic evaluations are performed to identify the problems for suggesting improvement and is shown in Table 2.

Table 2 Comparative chart showing the transformation of domestic architectural space and usability heuristic evaluation

Vaastu Shastra Principles	Former aesthetic variables	Case 1;Varikkassery Mana	Case 2; modern residence	Transformation of domestic architectural space	Usability heuristics evaluation
1.Examination and selection of site	Sovereignty	Site selection is based on context and User's choice to establish the political powers and territoriality	Irrelevant in the present-day context	Man –nature connect is missing in modern designs	There was Match between the built space and the real world. Site selection was based on five senses, thus establish a strong relation between man and nature. But not in practice now
2.Determining the orientation	Symbol and sign	Building's central axis aligned along the cardinal directions to depict symbolism	Symbolism established by aligning the buildings to the auspicious directions	The orientation Principles are still employs for the ease of use	Recognition of spaces based on orientation allows for easy identification of spaces
3. Building Measurement test	Cohesion	Fractional measurements in design. Every single module of measure is in resonance with the whole	A proportionate measurement system is not followed in accordance with modern materials and construction	Design standards are not confirming to User's ergonomic standards	Maintains Consistency because of the aligned traditional practice in moulding spaces. Modern designs are not adhering to standards reflecting the User's ergonomic data

(continued)

Table 2 (continued)

Vaastu Shastra Principles	Former aesthetic variables	Case 1;Varikkassery Mana	Case 2; modern residence	Transformation of domestic architectural space	Usability heuristics evaluation
	Rhythm	Spaces harmonize and resonate with each other. The microcosm is in unison with the Macrocosm	Modern interventions distracted the spatial resonance	Spatial resonance connecting microcosm and macro-cosm is not in practice	Flexibility and efficiency of use can be ensured if spaces are harmonize and resonate with each other
4. Vaastu Purusha Mandala	Geometry and spatial order	Vaastu Purusha Mandala provides geometry and spatial order	Vaastu Purusha grid system in design	Geometry and spatial order as per tradition and practice is still in use	Minimalist design as per vaastu grid system allows for decreasing the cognitive load
	Symmetry	Vaastu Purusha Mandala allows for symmetry in design	Symmetrical design	Symmetrical and Sequential order in designing spaces	Organizing and regulating guidelines helps to strengthen Traditional belief and imparts aesthetical quality
5. Zoning	Closeness	The zoning principle ensures proximity of spaces	Zoning principles followed in Modern residence	Aesthetics reveals the closeness of spaces as per cultural needs	Traditional zoning as per vaastu shastra allows for ease of use as per users choice

(continued)

Table 2 (continued)

Vaastu Shastra Principles	Former aesthetic variables	Case 1;Varikkassery Mana	Case 2; modern residence	Transformation of domestic architectural space	Usability heuristics evaluation
6. Door Openings	Permeability	Openings allows for permeable spaces, but not aligned along the same row	Permeable, openings are aligned. Minimal openings in design	Permeable spaces with unaligned openings offers the climatic comfort	Door penings as per vaastu shastra ensure both physical and physiological comfort
7. Proportion of the building	Proportion	Vaastu Shastra Proportion in design. Human scale for residences	Proportionate measurement is not employed. Monumental scale for residences	Exterior and interior spaces of modern dwellings are not in align with anthropometrics of the User	The proportion of the building as per vaastu is in align with human body and ensures a match between the truth, the good and the beauty
	Decoration	Traditional decorations	Traditional decorations in modern materials	Decorations are to be in proportionate with buildings and the surrounding	Decoration in align with natural materials allows minimalistic traditional design elements as per availability

6 Conclusions

The aesthetic consideration in Ancient sciences are remarkable, and it is taken care of the environment as a whole. Vaastu Shastra is a powerful way to communicate the traditional translations through spaces in harmony with Nature, Man, and the cosmic forces. The Vaastu design guidelines employ the surrounding context with future considerations of constructions, thus paves the way for its existence even today. Vaastu Shastra guidelines are derived from pragmatic approaches and maintain its continuity in design over time. The beauty of Domestic Architecture lies in its adaptability to new changes responding to the lifestyles. Public acceptance of the subject is widely in practice because of the capacity of vaastu shastra to maintain

cultural continuity. Heuristic evaluation suggests that, ancient building interface as product is adhering to the heuristics such as visibility, match between system and real world, user control and freedom, consistency, Error prevention, recognition, flexibility and efficiency, aesthetic and minimalistic design. Practicing vaastu Shastra in modern residences can utilize to enhance aesthetics in align with modern lifestyles. The principles of vaastu shastra merge with the lifestyles and needs in response to the surrounding environment, the resultant built and unbuilt spaces together constitute an environment. Vaastu shastra science developed by employing the traditional knowledge and the culturally stimulated design guidelines that accompany scientific reasoning; hence user perception is going along the concept intended. Without a conventional knowledge system integrating man, nature, and supporting activities, it is difficult to achieve a user-oriented space using scientific approaches alone. The concept of Vaastu shastra with scientific reasoning can employ in design practice to eradicate superstitious beliefs. A detailed study on different functional spaces in dwellings to identify the user issues are very much needed to carry over the essence in future designs. Upon various principles stated, the mismatches and disclarity present in the Proportionate measurement system principle are to get more emphasis in future researches.

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A Systematic Review of the Effects of Noise Characteristics on Human Mental Performance

Dipayan Das

Abstract There is a substantial effect of noise on human performance, especially for the tasks involving visual and mental concentration and/or cognition. This study aimed to systematically review the available literature related to the effect of noise on human cognitive performance. The literature search was performed on four electronic databases, including PubMed, Web of Science, ScienceDirect, and Google Scholar, and after applying the inclusion/exclusion criteria to 147 citations, 31 articles were finally selected for review. While exposure to noise had significant effect on the human cognitive performance, the size of the effect considerably depended on the nature of the noise and characteristics of the task. The noise type, frequency and intensity level were found to be the significant factors that influence human cognitive task performance, in terms of reaction time/time taken to complete a task and/or the count/percentage of errors. However, there is a limited research that evaluated the interaction effects of the noise characteristics on human cognitive performance. Hence, a more comprehensive research towards understanding the interaction effects of noise characteristics on human cognitive performance may be recommended.

Keywords Noise · Cognitive performance · Noise type · Noise intensity · Cognitive ergonomics

1 Introduction

Noise is pervasive in everyday life, and with gradual industrialization and technological advancement, noise pollution in the working and living environments has become a major challenge now-a-days. Exposure to noise at workplace has substantial effect on worker's health and performance [1]. Apart from the eventual auditory effects of noise [2], non-auditory effects, including development of fatigue [3], sleeping disturbance [4], annoyance [5], cardiovascular disease [6], and performance impairment [7] are well recognised. Further, communication difficulties, overexcitement

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and learning weakness, and lack of attention at workplace may be attributed to the exposure to noise [8]. Studies reported that exposure to noise adversely affected the ability to concentrate at work and impaired workers' performance [9].

There are several safety critical jobs which involve a high degree of cognitive skills, and the workers associated with such jobs often perform their activities in a noisy environment. For example, the job of a pilot which requires an extensive cognitive skill for ensuring safety of the passengers while being exposed to high levels of noise (around 80 dBA [10]) for long periods. Researchers reported that presence of background sound (music or noise) substantially reduced the cognitive performance compared to silence [11, 12]. However, it is evident that the cognitive performance is significantly influenced by the noise characteristics and the nature of the job [13, 14]. For instance, the reading performance was found to be the best with low intense classical music under normal illumination intensity condition [13]. In a steadiness test, accuracy was found to be highest for intermittent hiss-type (>2000 Hz) noise at 85 dB and lowest for fluctuating roar (<2000 Hz) at 95 dB [14].

Since there is a variation in the effects of noise characteristics on cognitive performance parameters, the current study aimed to systematically review the available research articles related to the effects of different noise characteristics on cognitive performance.

2 Methodology

2.1 Literature Search Strings

Research articles related to the effects of noise on cognitive performance were collected through a computer based literature search in four electronic databases, including PubMed, Web of Science, ScienceDirect, and Google Scholar with search strings as 'noise', 'cognitive performance', 'cognitive task', 'effects of noise' and 'human performance'. In addition, another strategic search was performed combining the search strings. The reference lists of retrieved articles were also checked.

2.2 Literature Screening and Inclusion/Exclusion Criteria

In the first phase of screening, literature retrieved from the computer-based search were evaluated based on their language. The articles written in language other than English were excluded from review. This was followed by screening of the articles for their relevance based on either their abstract or the full document. This helped in excluding the irrelevant and duplicate articles.

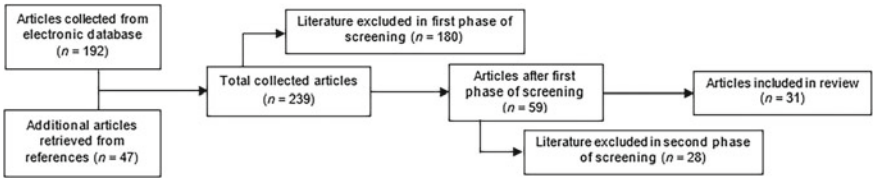

Fig. 1 Flow chart illustrating the literature selection process

In the second phase, the selected articles were filtered based on the inclusion/exclusion criteria. The primary inclusion criteria for the literature was documentation of effects of noise on cognitive task performance. Articles were excluded if: (a) the task evaluated was not a cognitive activity; (b) they did not measure the effects of noise on quantitative performance parameter; and (c) they were not available online as full reports. No restrictions were applied on the sample characteristics.

2.3 Data Extraction and Synthesis of Information

A checklist was prepared, and information regarding the year of publication, study location, sample characteristics, experiment details, and quantitative performance measures evaluated were extracted. Further, the effects of noise on cognitive performance were categorized based on the noise characteristics, including the type, frequency, and level of intensity.

3 Results

3.1 Literature Search Results

The total yield of the initial comprehensive literature search was 239 references. Among the 239 references, 11 articles written in other than English language, 7 duplicate articles and 162 irrelevant articles were excluded from the review. In the second literature screening phase, the inclusion/exclusion criteria was applied on the remaining 59 articles, and finally 31 articles were selected for review (see Fig. 1).

3.2 Description of Studies Included in Review

Of the 31 articles included in this review, 5 had included adolescence participants, 6 had included young adult subjects, and 4 had included participants who were in their

later adulthood. While 12 studies selected their potential participants from a mixed age group of young adults and those who were in their later adulthood, 2 studies included participants across all age groups (adolescence, adults, and elderly people). Table 1 presents the general and methodological information of the included studies.

3.3 Effects of Noise Type on Cognitive Performance

There is a substantial evidence of significant effect of noise type or noise source on cognitive performance. While the presence of high arousal music at 60 dBA resulted in poorer performance in recall task [11], reading performance was found to be significantly greater in presence of classical music at 45 dBA [13]. However, when compared to silence condition, the presence of music reduced recall performance [15]. The recall performance, further, substantially impaired when exposed to irrelevant or intelligible speech noise condition [16–21], and multiple noise sources, including road traffic noise, construction noise and ventilation noise [22]. Studies also revealed that presence of speech noise decreased performance in semantic memory task [20, 23] and comprehension task [24, 25]. Presence of environmental noise, comprising of barking dogs, traffic noise and irrelevant speech, resulted in prolonged reaction time in spatial attention task [12]. In mental computation task, no significant influence of exposure to music [26] and traffic noise condition [27] was observed. Researchers, further, reported that continuous type of noise had no significant effect on semantic performance, while the cognitive performance was substantially impaired in presence of intermittent and conglomerate noise of same intensity level (85 dBA) [28]. Similar results were also observed in working memory task when exposed to steady-state noise condition [29], and in case of an inspection task when exposed to intermittent and random noise condition [30].

3.4 Effects of Noise Intensity on Cognitive Performance

Several studies revealed significant effect of noise intensity on cognitive performance. For instance, studies reported that compared to quiet or low intense noise condition (<40 dBA), the recognition performance declined when exposed to a background noise at 80 dBA [31], office noise at 51 dBA [32], and speech noise at 64 dBA [33]. The recall performance, further, impaired in presence of motorway noise at 75 dBA [34] and road traffic noise at 70 dBA [35], when compared to a lower intensity level of respective noise exposure. In contrast, researchers reported that short exposure to industrial vehicle noise at 78 dBA did not significantly affect performance in memory task [36]. Studies also revealed that in comparison to low background noise (45 dBA) condition, visual/auditory attention significantly reduced when exposed to factory noise at 95 dBA [37]. However, in comparison to low background noise condition

Table 1 Description of the studies included in review

Reference	Study location	Participants	Cognitive task(s)	Experimental variable(s)	Performance measure(s)
[11]	United Kingdom	20 students aged 18–23 years, 10 adolescents aged 14–16 years, 10 working adults aged 25–50 years	Stroop neuropsychological screening test, behavioural memory test, free and delayed recall task	Relaxing positive low arousal music, aggressive negative high arousal music and background noise at a level of 60 dBA, and silence condition	Mean reaction time, mean score of correct recall
[12]	Austria	10 volunteers (5 males, 5 females), mean age of 28 years	Visual spatial attention task	Background noise: 60 dBA and without noise condition	Mean reaction time
[13]	Taiwan	10 female students between aged 19–22 years	Reading task	Noise type (factory noise, classical music, and pop with lyrics), noise intensity (45 dBA, 65 dBA, 85 dBA), illumination intensity (200 lx, 600 lx, 1000 lx)	Mean score of correct answer
[14]	Iran	10 male students, mean age of 24.51 years	Steadiness test	Noise type (steady, intermittent, and fluctuating), sound level (75 dB, 85 dB, 95 dB), frequency characteristics (<000 Hz, >2000 Hz)	Speed, errors, and accuracy
[15]	United Kingdom	76 students (33 males, 43 females), mean age of 17.07 years	Reading comprehension task, prose recall task, mental arithmetic task	Noise type (silence, office noise, music)	Mean score of correct answer, word recalled, answer sum
[16]	Germany	24 students (4 males, 20 females) aged 20–33 years	Serial recall task	Sound condition (silence, pink noise, continuous and variable speech-like noise, masked speech)	Percentage of errors

(continued)

Table 1 (continued)

Reference	Study location	Participants	Cognitive task(s)	Experimental variable(s)	Performance measure(s)
[17]	France	35 individuals aged 23–59 years	Serial memory task	Sound type (silence, printers noise, intelligible speech, non-intelligible speech, phone rings noise)	Percentage decrease in performance
[18]	Sweden	96 teachers (37 males, 59 females) aged 35–65 years	Cued recall task	Noise condition (silence: 38 dBA, road traffic and speech noise: 62 dBA)	Mean score of correct answer
[19]	United Kingdom	132 undergraduate students	Serial prose recall task, free prose recall task, mental arithmetic task	Sound characteristics (speech noise: 65 dBA, office noise with speech: 65 dBA, quiet condition)	Accuracy score, task completion time
[20]	Sweden	96 students aged 18–20 years	Episodic memory task, face and name recognition task, semantic memory task	Noise condition (silence environment: 32 dBA, road traffic noise: 66 dBA, irrelevant speech noise: 66 dBA)	Mean score of recall and recognition text, face recognition, word fluency, and accuracy
[21]	Germany	20 students (2 males, 18 females) aged 19–27 years	Serial recall task, mental arithmetic task, verbal logical reasoning task	Sound condition (silence condition: soft pink noise at 25 dBA, speech noise: 55 dBA, good intelligible speech noise: 35 dBA, bad intelligible speech noise: 35 dBA)	Percentage of errors

(continued)

Table 1 (continued)

Reference	Study location	Participants	Cognitive task(s)	Experimental variable(s)	Performance measure(s)
[22]	South Korea	20 students (11 males, 9 females) aged 21–28 years	Free recall task, word comprehension task	Combinations of road traffic noise (35 dBA), construction noise (30 dBA, 40 dBA, 50 dBA), ventilation noise (30 dBA, 40 dBA, 50 dBA)	Percentage of correct response and word recalled
[23]	Sweden	12 normal-hearing subjects (mean age = 29.5 years), 12 elderly subjects (mean age = 69 years), 12 young hearing-impaired subjects (mean age = 30.3 years), 12 elderly hearing-impaired subjects (mean age = 70.7 years)	Lexical test, semantic test, matching name test	Sound characteristics (silence condition, speech noise: 75 dBA, ICRA noise: 75 dBA, Hagerman noise: 75 dBA)	Accuracy, mean reaction time
[24]	Germany	22 children aged 6–7 years	Speech perception, short-term memory, sentence comprehension	Noise type (speech noise, train noise), noise intensity (36 dB, 59 dB)	Accuracy
[25]	Sweden	187 children (98 boys, 89 girls) aged 12–13 years	Reading and word comprehension task, mathematical reasoning task	Noise condition (silence: 38 dBA, road traffic and speech noise: 62 dBA)	Mean score of correct response
[26]	United Kingdom	142 students (111 males, 31 females) aged 16–18 years	Reading comprehension, logical problem solving	Sound characteristics (silence condition, instrumental noise, vocal noise)	Mean number of correct response

(continued)

Table 1 (continued)

Reference	Study location	Participants	Cognitive task(s)	Experimental variable(s)	Performance measure(s)
[27]	Germany	102 persons (51 males, 51 females) with the mean age of 23.8 years	Grammatical reasoning task, mathematical processing task	Noise condition (silence: 43.6 dBA, even traffic noise: 20% heavy vehicles and 40% heavy vehicle, lumped traffic noise: 20% heavy vehicles and 40% heavy vehicle	Percentage of correct responses
[28]	United Kingdom	40 female members, 57 students, 70 students aged 16–19 years	Semantic processing task, syntactic reasoning task	Noise characteristics (quiet condition: 45 dBA, continuous, intermittent, conglomerate noise: 85 dBA)	Mean number of items completed and errors
[29]	United States	45 participants (10 males, 35 females), mean age of 21.5 years	Verbal working-memory task	Noise condition (quiet, steady-state speech-spectrum-shaped noise: 0 dB SNR, −5 dB SNR, −10 dB SNR)	Mean percentage score of correct word recognition
[30]	United States	15 students aged 21–28 years	Inspection task (easy and difficult)	Noise characteristics (no-noise condition: 40 dBA, continuous, intermittent, random noise: 8 dBA)	Percentage of correct detection
[31]	Australia	32 participants (13 males, 19 females), mean age of 21.84 years	Letter span task, grammatical reasoning task, mathematical reasoning task, cued-recall task	Noise condition (quiet vs. 80 dBA noise), mode of delivery (visual vs. auditory), language background (native English vs. non-native English)	Mean recall time, mean score of correct recall

(continued)

Table 1 (continued)

Reference	Study location	Participants	Cognitive task(s)	Experimental variable(s)	Performance measure(s)
[32]	Sweden	47 persons (20 males, 27 females), mean age of 26 years	Word recall task	Noise condition (high: 51 dBA, low: 39 dBA), noise type (river movie with sound, only river sound, silence, and office noise)	Mean number of words recalled from the correct list
[33]	Sweden	32 participants (23 women, 9 men) aged 18–34 years	Word recall and recognition of sentence	Speech noise at intensity level of 24 dBA and 64 dBA	Mean score of correct recall, and correct answer
[34]	Sweden	45 students (23 males, 22 females), mean age of 24 years	Short-term memory task, mental arithmetic task	Noise condition (quiet: background laboratory noise of 30 dBA, moderate: motorway noise of 55 dBA, high: motorway noise of 75 dBA)	Mean score of letters missed and correct answer
[35]	Germany	24 students (7 males, 17 females) aged 19–31 years	Stroop task, mental arithmetic task, verbal serial recall task	Road traffic noise at intensity level of 50 dBA, 60 dBA, 70 dBA	Percentage of errors
[36]	Sweden	24 male subjects aged 21–30 years	Grammatical reasoning task, short-term memory task	Noise only condition, vibration only condition, noise and vibration condition, and control condition	Reaction time, mean of errors
[37]	Iran	54 participants (27 males, 27 females) aged 23–30 years	Integrated visual and auditory test	Noise characteristics (background noise: 45 dBA, exposure noise: 75 dBA, 85 dBA, 95 dBA)	Mean of attention score

(continued)

Table 1 (continued)

Reference	Study location	Participants	Cognitive task(s)	Experimental variable(s)	Performance measure(s)
[38]	Canada	20 active duty male soldiers, mean age of 24.2 years	Target detection and identification	Battlefield noise of 87 dBA and quiet control condition (low-level background sound <54 dBA)	Shooting accuracy and percentage of delayed shots
[39]	Serbia	123 medical students (43 males, 80 females), aged 24–26 years	Mental arithmetic task	Noise characteristics (quiet condition: 42 dBA, noise condition: 88 dBA)	Accuracy of shallow, intermediate, deep
[40]	Sweden	38 females, mean age of 24.6 years	Simple reaction-time task, embedded figure task, bulb task, search and memory task, proof reading task	Noise frequency (low, flat: reference level)	Mean reaction time, mean of correct response, lines searched, and errors detected, percentage of correct target letters
[41]	Iran	89 students (54 males, 35 females)	Stroop task, Cognitrone test	Noise frequency (low: <250 Hz, high: 500 Hz), noise intensity (50 dBA, 70 dBA), silence ambient condition	Mean of sum hits, sum correct rejections, incorrect reactions, and working time

(<55 dBA), there is no significant influence of high battlefield noise (87 dBA) [38] and traffic noise (88 dBA) [39] on human accuracy.

3.5 Effects of Noise Frequency on Cognitive Performance

It is evident that noise frequency had more significant impact on cognitive performance than other noise attributes, including the noise type and intensity level [14]. Moreover, the 'hiss' type noise of frequency >2000 Hz substantially reduced the performance speed and accuracy in comparison to the counterpart, i.e., 'roar' type noise of frequency <2000 Hz. In contrast, researchers reported that low-frequency noise negatively influenced performance on two tasks sensitive to reduced attention and on a proof-reading task [40]. Even exposure to low frequency (<250 Hz) and high frequency noise (500 Hz) resulted in improved performance speed in multiple cognitive task [41].

4 Discussion

In the reviewed literature, there was extensive evidence that noise characteristics have significant influence on human cognitive performance. This review included 31 articles, which each evaluated the effects of various noise attributes on different cognitive task performance. Most of these cognitive tasks were the recall and recognition activity, reasoning and mental computation activity, and reading and visual perception. The speed or mean reaction time was observed as the mostly used quantitative measure of cognitive performance in the research groups, followed by proportion of errors and accuracy.

Several studies have reported that exposure to any noise condition, such as road traffic noise, irrelevant speech noise, office noise, construction noise, and music, substantially impaired the recall and recognition performance [15–23]. Further, the recall and recognition performance was found to be declined with increasing noise intensity level [31–35]. In this case, the exposure duration may play a confounding role, since researchers reported that short duration of industrial vehicle noise at 78 dBA did have significant effect on memory task [36]. Interestingly, there was no significant effect of background noise on mental computation task performance [26, 27]. While the accuracy in auditory/visual attention task was substantially impaired by high level of factory noise [37], there was no significant effect of high battlefield and traffic noise was observed on human accuracy [38, 39]. Moreover, exposure to low frequency noise resulted in reduced attention and increased errors [40].

Inclusion of only the articles that evaluated quantitative performance and lack of access to literature in languages other than English are the limitations of the current review.

5 Conclusion

The current review clearly demonstrates that there is a significant influence of noise characteristics on cognitive performance. However, there is a limited research regarding the interaction effects of the noise characteristics on cognitive performance. Hence, a more comprehensive research towards understanding the interaction effects of noise characteristics on cognitive performance may be recommended.

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Design of Safety Helmet for Construction Workers and Evaluation Using Digital Human Model

Ashish Thulkar and Anirban Chowdhury

Abstract A personal proactive headgear (construction helmet) is important and mandatory for construction workers to use during their work. Construction helmets are used in both indoors and outdoors. It protects the head from any injury caused due to the fall of stone, brick, tools, etc. As there are different types of construction helmets on the market; however, helmets have multiple problems such as low strength, uneven thickness of the outside shell, incorrect helmet sizes are not based on Indian anthropometric data, lack of air inlets, low-quality materials, and unattractive design. This paper attempts to conceptualize and compare a helmet design with advanced safety features, comfort, strength, and aesthetic appeal. To achieve the output design process is been used and create multiple ideas. A total of two helmets were conceptualized through brainstorming and concept sketching to achieve aesthetic form. The CAD models for these two helmets were developed using CATIA V5-R19. The ABS (Acrylonitrile butadiene styrene) material is used on a helmet and stress-strain analysis was conducted using the same software to evaluate two concepts. The final concept is further evaluated using CATIA ergonomic DHM (digital human model) to ensure comfort. After analysis, the final selected concept was found to be strong, comfortable, and aesthetically pleasing in terms of masculine, stylish design. The physical model of the helmet needs to be made for better analysis of all factors.

Keywords Design · Digital human model (DHM) · Ergonomics · Helmet · Safety

1 Introduction

The Safety of the construction worker is more important during the work. It is essential to use a safety helmet for the protection of the head. The helmet protracts head injury caused by fallen objects in the various work environment such as building construction, bridge construction, mining, tunneling, quarrying,

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shipbuilding, industrial work. Head injuries caused by a fallen object are usually serious and sometimes fatal [1]. In addition to safety, comfort is another important ergonomic factor that is especially required for a worker who is working with such personal portative equipment for a longer duration. A proper fit helmet improves comfort during work. Construction workers work in different areas and it is required to provide safety and comfort with personal portative equipment. The different working environment affects the design of helmet differently. Construction workers are the second largest employer in India after agriculture. It gives jobs to 44 million people and contributes 9% of GDP [2]. However, the construction workers are working in most un-protracted workplaces without personal protective equipment as compared to other industries in the country. As per the study fatality rate on construction sites is five times more than any other manufacturing industry [3]. In this context, the application of the ergonomics principle for helmet design is important. It is also crucial to dig into the literature on the helmet as a personal proactive equipment.

2 Literature Review

2.1 Ergonomic Factors for Helmet Design

During helmet design, the safety factor is very important. The strength of the helmet is also depended upon the selection of material. The form of the helmet plays a very important role in improving the strength of the helmet and overall aesthetic look [4]. The products like the helmet are always in continuous use for a longer duration. The right dimensions of the product will improve the ease of use and comfort of the design [5]. Anthropometry provides a dimensional measurement of the Indian human body with the required to analyze the strong ability of the human body and determine physical geometry. The Design of the concretion helmet required the head circumference of a human head. The human head length and breadth must be considered when designing the helmet's inner shell. (See Table 1), [6]. The construction helmet design should be lightweight not more than 400 g [7, 8] as per the Bureau of Indian standers. The lightweight design will enhance the user's comfort and productivity.

Table 1 Anthropometric data of Indian male and female [6]

Population	Percentile	Head length (mm)	Head breadth (mm)	Circumference (mm)
Indian Male	5th	174	135	520
Indian Male	50th	187	147	544
Indian Male	95th	199	157	574
Indian female	5th	163	132	500
Indian female	50th	176	142	520
Indian female	95th	192	155	549

2.2 Ergonomic Evaluation of Product in Virtual Environment

To study and analysis the safety and comfort the computer added design and digital human modeling is used. CAD plays important role in testing the safety of the helmet. It also helps to analyze the impact of load on helmet shells and how much damage it can cause to the head [9]. As per the Bureau of Indian Standards, the helmet should withstand 10 kg of impact load [7, 8].

The comfort and fitting of the helmet can be analyzed by using a digital human model. The digital human model is the method in which ergonomic dimensions are considered during the design process and applied to the end-user model. The analysis shows how DHM is affected by the design. DHM offers a new opportunity to incorporate ergonomic principles in design in the initial stages of the design process [10]. It helps to solve various problems at the early stages of design.

Although, many helmets were designed in the past, aesthetic aspects were not considered for safety helmet design along with ergonomics. In this study, an attempt has been made to conceptualize and compare helmet design that has safety features, comfort, strength, and aesthetic form.

3 Methodology

A total of two helmets were conceptualized through brainstorming and concept sketching to achieve aesthetic form. The CAD models for these two helmets were developed using CATIA V5-R19. Then, a suitable material was applied to the helmet to improve the strength, in the CAD environment. The stress and strain analyses were also conducted using the same software. This analysis helped to understand the safety feature of helmets. Later, a simulation-based research approach was taken; and, the CATIA ergonomics evaluation module was applied to ensure the helmet size, comfort and head fit using digital human models.

3.1 Designing Helmets

3.1.1 Ideation

In this study, different ideas were created for the exterior of the construction helmet. The ideas were developed based on form, shape, size, and aesthetic look. Inspiration was drawn from keywords such as masculinity, technology, and modern look. In the initial stage of ideation design, the standard form government of India considered [7, 8, 11]. As Design has to satisfy all standards to be manufacture in future scope.

A different visual language is created by changing the patterns of the outer shell of the construction helmet. It will also lend strength to the helmet. Extruded pattern

Fig. 1 Construction helmet concept 1

created which joins rare of the helmet to front to provide masculinity and modern look to the helmet. One of the ideas created a front flat cubical structure with mostly use for putting construction worker names, titles, etc. It also helps to mount the torch. In some ideas front cap of the helmet marge with the overall form of the helmet to give modern look and improve strength.

For inner shell attachment, a different pattern of stripes was created which will hold the head position. Some ideas are simple to minimize the weight and provide ventilation. Some are created so the head can be held in place properly and have small holes for air intake.

3.1.2 Conceptualization

All ideas are evaluated based on their form shape, masculinity, modern look aesthetic, and strength. The outer shell idea was combined with different ideas for the inner attachments. Modify the form shape and add detailing to the idea to create the concept. After the same evaluation process, two concepts were created that follow the same aesthetic language but represent different shapes and styles.

In Concept 1, the cap on the front is centered with small extrusion, providing extra strength for the top. The top back has a rounded extruding portion which provides strength to shell and techno look (see Fig. 1).

Concept 2 has a fully covered front cap with a given modern look to the helmet. Extrude cubical structure provides more strength and also provides support for accessory attachment. The rare of the helmet also has bigger extrusion (see Fig. 2).

3.2 Stress Strain Analysis Using CATIA

The 3D computer-aided design has been created for two concepts. CATIAV5 –R19 CAD computer software package used to create the model. The dimensions consideration is taken as per the Indian standers for protective equipment [7, 8, 11]. The CAD is created in the two-part first one is the outer shell and the other is inner

Fig. 2 Construction helmet concept 2

Fig. 3 Computer added design of construction helmet

fitting. For the inner fitting, the dimensions are considered as per Indian Anthropometric data [6]. The inner shell can be attached to the outer shell with a simple clip lock mechanism. A strap adjustment mechanism is provided at the back so that the user can adjust the size as per requirement. The main purpose to create a 3D model is to test the design and material with loading condition and analyses the impact of design on human with the help of digital human model (see Fig. 3).

The Maximus permissible limit of 100 N (as per BIS standards) [7, 8] is considered as impact force on the construction helmet design. Material consideration for the outer shell is ABS (Acrylonitrile butadiene styrene). It will increase the overall strength of the helmet. The material for the inner shell is considered PP (Polypropylene) which provides more strength. Given smooth surface finish. The standard Material specification used as per CATIA V5 R- R19 (see Table 2). For this study, the helmet is fixed from the bottom because in practice helmet is fixed with our neck so it is considered as bottom fixed. 100 N force applied on the top surface of the helmet. The same condition is applied for both concepts. In these cases load has been applied on the top shell and various result of stress, strain, and total deformation has been taken and analyzed.

Table 2 Material specification for helmet found in CATIA V5-R19

Material	ABS plastic	Polypropylene
Young's modulus	2.24e+009 N/m^2	1.34e+009 N/m^2
Poisson's ratio	0.36	0.392
Density	1040 kg/m^3	913 kg/m^3
Yield strength	2e+007 N/m^2	3.03e+007 N/m^2
Coefficient of thermal expansion	8.57e-005/Kdeg	9.05e-005/Kdeg

3.3 DHM Based Evaluation of Helmets

The digital human model is a method in which ergonomic dimensions are considered during the design process and applied to the end-user model. It helps to analyze how it is affected by the design. In this study, CATIA V5 R 19 computer application is used to create a digital human model. As per the anthropometric data, the changes in the model were made. The male and female models were created considering the 5th, 50th, and 95th percentile. For analyzing the helmet impact on the end-user main dimensions considered like head breadth, head length, the circumference of the head, circumference of the neck (See Fig. 4).

4 Results and Discussion

Initial concepts of helmets were filtered based on aesthetic qualities such as masculine, stylish, and techno-look after taking responses from designers. Then, the best concept was chosen for further analysis. It was decided to use ABS as it is a comparatively affordable material and provides a better look and feel. To improve the strength of the helmet ABS is a better material than PPE for the outer shell. The stress and strain analysis confirm that the stability and strength of the ABS helmet are better than the PPE helmet, currently available in the market. The DHM analysis results ensure that the selected helmet is comfortable and easily fitting to the human head.

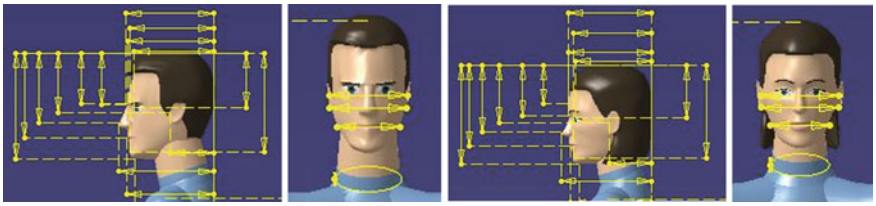

Fig. 4 Digital human model with Indian anthropometric dimensions

4.1 Resolutions of Stress and Strain Analysis

As per the static analysis in CATIA V5 R 19 perform on the two construction helmet concepts. The maximum stress distribution shows on the joint of the front cap and side of concept 1 which is 4.47e+004 N/m^2 (see Fig. 5a). The maximum displacement at to rib corner is 0.196 mm (see Fig. 5b). The maximum stress distribution on the front corner and back of concept 2 is 6.66+004 N/m^2 (see Fig. 6a). Concept 2 shows maximum displacement at to rib corners which is 0.0159 mm (see Fig. 6b). Concept 2 perform better than concept 1 though both the concept are within the permissible limit as per The Bureau of Indian stranded while considering stress and strain.

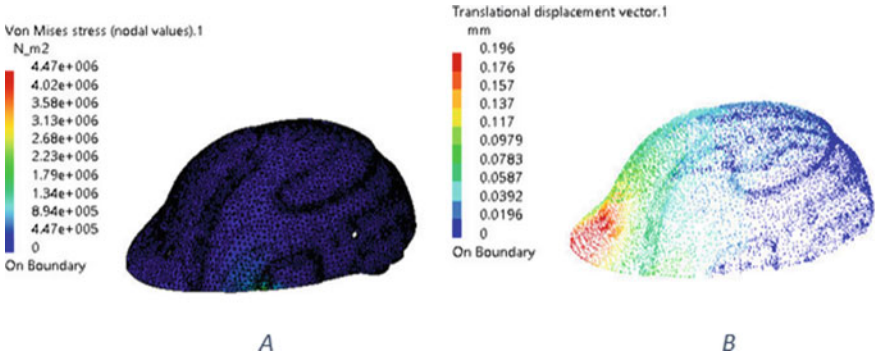

Fig. 5 **a** Stress analysis on concept1, **b** displacement analysis on concept 1

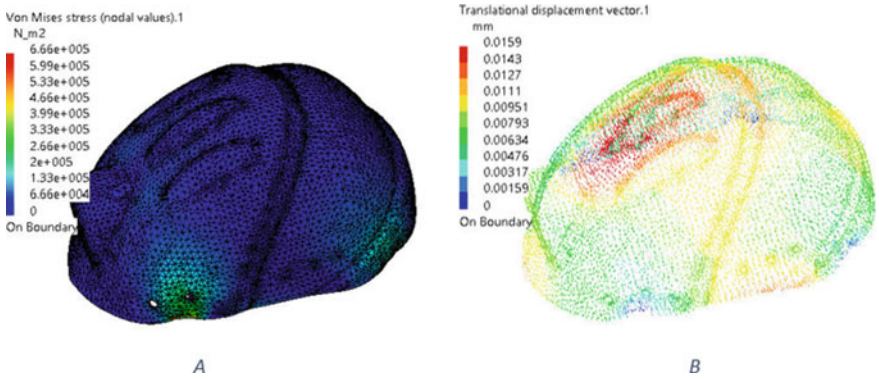

Fig. 6 **a** Stress analysis on concept 2, **b** displacement analysis on concept 2

4.2 Fitting Helmet to Human Body Anthropometric Fit

As per the anthropometric fit in CATIA V5 R 19 ergonomic analysis module. The concept 1 of helmet fit the 5th percentile of Indian male with gape on side front and back. Which can be reduced by back adjustment strap gear (See Fig. 7a). The concept 1 of helmet fit the 50th percentile of Indian male with small gape in front and side which can be minimized by back adjustment strap gear (See Fig. 7b). Concept 1 of helmet fits comfortably on 95th percentile of Indian male so no adjustment required. (See Fig. 7c). Concept 1 of the helmet fits the 5th percentile of Indian female with a big gap on the side, front, and back which can be minimized using backstrap adjustment (see Fig. 8a) the concept 1 of the helmet fits the 50th percentile of Indian female with side and front gape which can be reduced with the help of backstrap adjustment. (See Fig. 8b). Concept 1 of helmet fits comfortably on 95th percentile of Indian female with small gape witch can be reduced by using backstrap adjustment (see Fig. 8c).

Concept 2 of the helmet fit the 5th percentile of Indian male with gape on side and front which can be reduced by back adjustment gear strap. (See Fig. 9a). Concept 2 of the helmet fit the 50th percentile of Indian male with small gape in front which

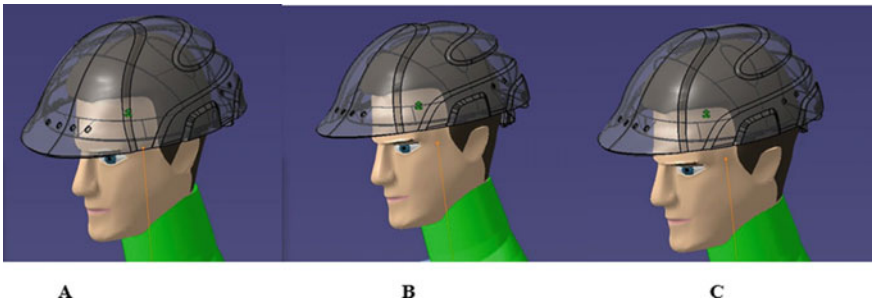

Fig. 7 **a** 5th Percentile Indian male with concept 1, **b** 50th percentile Indian male with concept 1, **c** 95th percentile of Indian male with concept 1

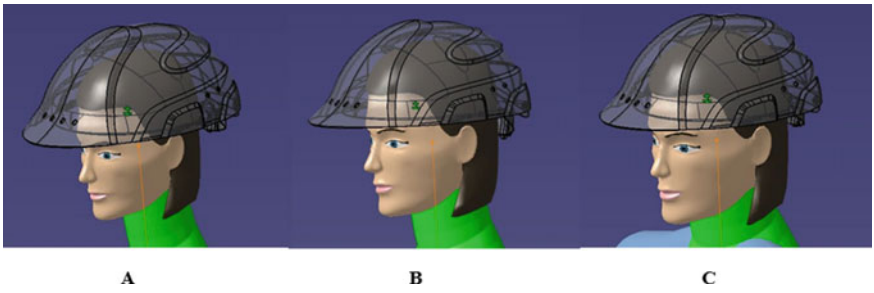

Fig. 8 **a** 5th Percentile Indian female with concept 1, **b** 50th percentile Indian female with concept 1, **c** 95th percentile of Indian female with concept 1

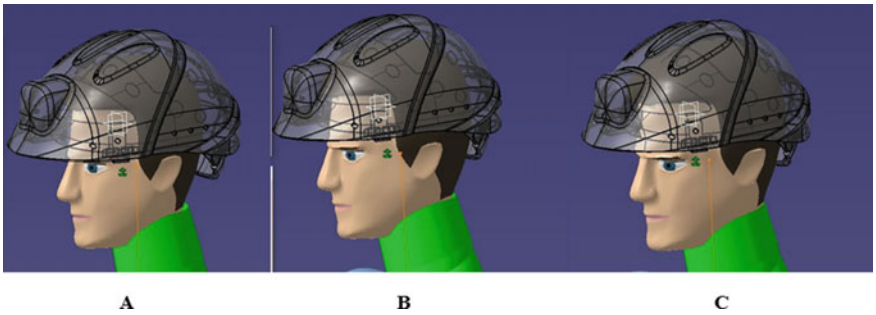

Fig. 9 **a** 5th Percentile Indian male with concept 2. **b** 50th percentile Indian male with concept 2. c 95th percentile of Indian male with concept 2

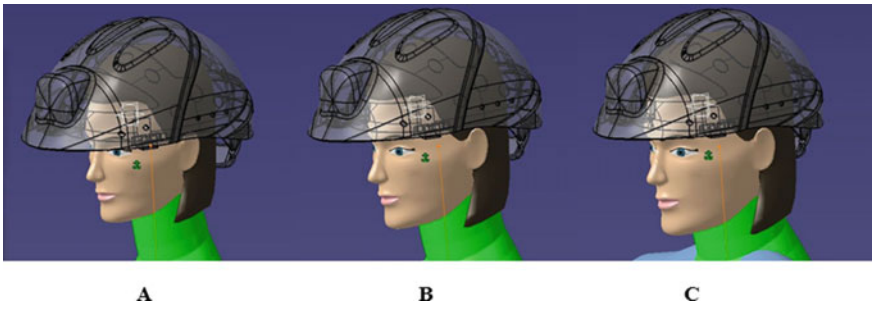

Fig. 10 **a** 5th Percentile Indian female with concept 2. **b** 50th percentile Indian female with concept 2. **c** 95th percentile of Indian female with concept 2

can be reduced by adjustment gear strap. (See Fig. 9b). Concept 2 of the helmet fit comfortably on the 95th percentile of Indian male no adjustment is required (see Fig. 9c). Concept 2 of helmet fits 5th percentile if Indian female with a big gap in front, back, and side which can be reduced by using back adjustment strap gear (see Fig. 10a). Concept 2 of helmet fit on 50th percentile of Indian female with gape in front and side which can be reduced by using adjustment gear strap (see Fig. 10b). Concept 2 of helmet fits comfortably on 95th percentile of Indian female with small gape which can be adjusted by using backstrap adjustment gear (see Fig. 10c).

5 Conclusion

This study is attempted to design, compare and evaluate different shapes, forms of construction helmet and how it affects the strength and anthropometric fit on Indian digital human model. Both helmet concepts are comfortable and aesthetically better than the existing helmets in terms of masculine, stylish, and tecnolook. The strength

of the helmet is batter with ABS material on the outer shell. The fitting of the inner shell can be adjustable with back strap adjustment. Also, a chin strap can be provided for a more stable fit. However, it is possible to do further study on how helmet design impact the Indian Digital human (DHM) model using Rapid upper limb assessment (RULA) analysis. It will help to understand the load on neck and chances of associated of neck discomfort. Nordic questionnaire method also can be used for further study and analyses the effect of helmet on human body. Kinematic analysis or drop test can further be conducted in near future.

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An Exploration of Animation Support to Documentary Film for Better Communication

Subash Rai, Swarnadeep Nath, and Debkumar Chakrabarti

Abstract Documentary film is one of the best conventional practice for information preservation and dissemination, and digital technology has expanded possibilities to add on benefits. While looking for further scope, it appears that direct real life shooting based production is lacking in covering many details that was intended to display. To address such creative gaps, the present study looks into inclusion of innovative multimedia content such as 2D or 3D animations that can enhance a specific purpose to deal with details. This deliberation expresses an experiment where a documentary film (narration and direct shooting) was made on a folklore Bardwi Shikla which has been passed on through generations within the Bodo community of North-East India following an oral tradition and it has many finer issues that one needs to internalise with imagination. It was to initially see whether the sentimental details described there in reaches across the community and to others as well. Based on feedback responses on the film after screening to users (both Bodo and non-Bodo origin volunteers) inclusion of animated illustration contents in support of explaining some finer aspects that could not be shown through real life shooting and voice clarification confirms added value towards better communication. A conclusion is drawn that a context specific animation support in digital documentary production could serve both archive as well as add on editing facility for flexibility and better expression of the content.

Keywords Documentary film · Animation support · Better communication · Folklore

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1 Introduction: Conceptual Background

1.1 Documentary Film

A non-fictional motion picture analysing facts and real-life incidents with a purpose to educate and inform is known as a documentary film. It is intended to "document reality, primarily for the purposes of instruction, education, or maintaining a historical record [1]. Documentary Film is organized to present an overview of central issues and then to discuss different genres [2]. The era of documentary film commenced in the late nineteenth century, and Nanook of the North, released in the year 1922 by Robert Flaherty, an American silent documentary is considered to be the world's first documentary.

John Grierson coined the term documentary by employing it to the work of the Robert Flaherty's Moana, released in the year 1926, a journal on the day-to-day life on the populace of the South Seas island. He defined documentary as the "artistic representation of actuality", a definition that has proven durable because it is so very flexible [3]. The subjects of the documentary film are oriented around real-life events with raw film footage of places and individuals, and also include commentaries explaining the sequences in it in a dramatic way. The approaches and forms of the subject may vary:

It can be a trip to exotic lands and lifestyles, as was Nanook of the North (1992). It can be a visual poem, such as Jori Iven's Rain, released in the year 1926–a rainy day set to a piece of classical music, in which the storm echoes the structure of the music. It can be an artful piece of propaganda. Soviet filmmaker Dziga Vertov, who ardently proclaimed that fiction cinema was poisonous and dying and that documentary was the future, made Man with a Movie Camera released in the year 1929 as propaganda both for a political regime and a film style [4].

With the emergence of increasingly accessible and affordable digital technology, audio-visual media has unlocked myriad possibilities for the documentation, creation, preservation, and sharing of digital content, data, and information [5].

1.2 Animation

Animation is the simulation of movement shaped by a sequence of pictures in which figures are employed to form an illusion so as to appear as moving images. And it is derived from a Latin term animare, which means "to give life" and in the animated movies contextual it means the artificial design of the illusion of movement in inanimate lines and forms. According to Paul Wells: A working definition, therefore, of animation in practice, is that it is a film made by hand, frame-in-frame, providing an illusion of movement which has not been directly recorded in the conventional photographic scene [6].

In traditional animation, in order to create the animated series, each frame is drawn on a celluloid transparent paper. It is considered as conventional 2D animation. For instances Disney movies like Aladdin released in the year 1992 and The Lion King released in the year 1994. The 2D animation with Vector-based is described as the 2D animation, which is unconventional and controlled by, vectors rather than pixels.

In the field of entertainment, animated films are big business. Some of the top earning films of all time are animated. The top earning film to date, 'Avatar', shows how far technology has come in terms of creating realistic fantasy environments and creatures that interact successfully with real actors. Animation also plays an important role in modern business. It is frequently used in advertising to grab the attention of the audience. It is a useful tool for keeping the audience engaged and for communicating information quickly and effectively. Animation is often used in education as a highly effective tool, especially for younger age groups. It can be used as an effective tool for communication in pedagogy that can improve students' academic performance if used properly [7]. Animation has developed very significantly in recent years and are being applied in many educational settings [8].

1.3 Animation and Documentary Films

In the recent years a new genre of movie has emerged known as animated documentary and it is a blend of animation and documentary. This genre commenced with Winsor McCay's twelve minute long film The Sinking of the Lusitania in 1918 which used animation to portray the 1915 sinking of RMS Lusitania, an event of which no recorded film footage is known to exist. This shows that animation can communicate those which cannot be delivered in live action. It has been however opularized with movies Brett Morgen's Chicago released in the year 2007, Marjane Satrapi's Persepolis released in the year 2007 and Ari Folman's Waltz with Bashir released in the year 2008.

In recent years, some of the Oscar-winning documentary films such as Searching for Sugar Man and Bowling for Columbine, and, more recently, a very popular—Point and Shoot and Meet the Patels have count on animation to tell compelling nonfiction stories in nontraditional methods. Audiences have grown habituated to this technique and nonfiction filmmakers have learned to adopt with varying degrees of success. It's now largely accepted that even observational documentaries involve some degree of manipulation. If anything, by using animation in a documentary, the manipulation is more explicit. Animation can serve various purposes. When done well, it can make talking-head interviews more dynamic or fill in gaps in archival material. It can also help create a strong visual style while tapping into the broader theme of the film.

Ergonomics impact us all in all design field, so does in documentary film making also. Humans are genetically, biologically and socially storytelling animals: narrative structures are a fundamental way of experiencing, exploring and thinking about reality. Stories come to us with invitation to both cognitive and emotional responses

and activities and those two dimensions are linked intimately in real life, fiction and documentary forms. Non-fiction genres have different variations of rhetorical and narrative structures and they follow patterns of social and psychological involvement that are also used in real life experience and interaction. The role of narrative, emotion and memory in different forms of documentary film is important because the mediated memories have a wide spread function in our culture and society [9].

2 Purpose of the Study

The above study shows that animation and documentary film has a fair amount of advantage when it comes to expressing finer aspects in details of any given concepts, the purpose of which the study was done and to verify the theory an innovative approach of documentary film making on folktale of ethnic Bodo tradition has been chosen as the subject for experiment.

Bodos are the ethnic community of Assam, North-Ease India. Bodo community is one of most progressing community in the North-East India. The Bodos population is mostly concentrated in four districts in the west of Assam called Boland Territorial Region (BTR). They have a very rich ethnic traditions and culture, but due to globalization and rapid development in the region the ethnic traditions of Bodos have become vulnerable with the young generations' inclination towards western culture and easily accessible technology. Today is the age if digital technology. Video and film have been the popular means of communication and information. In the post independent India, Documentary film have played a vital role of nation building, integration, and development [10]. However, Documentary film has still been a new concept in Bodo society. The Bodo film industry have completed three odd decades, but has develop very little [11].

3 Methodology

A twofold survey was conducted on 60 participants (Bodo and Non-Bodo origin) comprising randomly selected student volunteers. 40 student volunteers were chosen from Department of Multimedia Communication and Design (MCD), Central Institute of Technology Kokrajhar and 20 students from kokrajhar Govt. College, Assam. Respondents were asked to answer the questionnaire of multiple choices format, which were passed to them through online google form as well as offline form. The objectives were to understand their perception on the issues and to address the issues with probable solutions.

The first stage of the twofold survey was conducted at the beginning with a select documentary shared online and offline form along with the Questionnaire form to all participants. The documentary was a compilation of video clips taken from online archive.

In the second stage of the twofold survey, inputs from the discussion held with the group of experts of Bodo tradition and culture were considered to make the new film that was showcase in the second phase. A set of Questionnaire with newly created documentary was shared to all participants. The documentary contained animation sequence and live-action sequences that was diligently edited to make narrative smooth transition designed for better communication.

3.1 Discussion from the Group of Experts of Bodo Tradition and Culture

Since the study area was selected to be the folk tradition of Bodo Ethnic community, eminent folklorist from BTR was selected for discussion on the Bodo folklore. From the discussion we could know about the folklore Bardwi Sikhla, one of the important folk tradition practiced by Bodo people. An authentic information was gathered about the egendary tale of Bardwi Sikhla. The gist of folklore Bardwi Sikhla confirmed is as follows:

Bardwi Sikhla is a fairy who possesses a natural power to control air and water. She has a beautiful long loose dark hair and dressed in dokhona. She arrives in the spring season (month of falgun and Chaitra of Bangla Son) season. She is lively and showers rain, hailstorm and thunder whenever she goes. She washes off the dirt and clean the environment that was pale and dry, and thus refreshes the atmosphere and makes it green. The courtyards those were full of dirt and dust, fallen dried leaves are clean. The plants and trees starts blossoming new leaves and greenery can be seen everywhere. By the time Bwisag arrives (mid of April month), Bardwi Sikhla have already cleaned and made the environment fresh and green. Bardwi Sikhla is commemorated whole heartedly by the Bodo people to welcome monsoon season through Bwisagu festival. This festival is celebrated by the Bodo people annually during mid of April (in Bodo it is called Bwisag). The singing and dancing hold a special place when it comes to community identity of Bodos. Bodos have nearly nineteen dance forms and they are performed on and off stage during festivals and cultural demonstrations. Among them is Bardwi Sikhla dance form. It is also said to be the enactment of the nature of Bardwi Sikhla.

The discussion also reviled more understanding about the Bodo folklore Bardwi Sikhla. The following information were gathered:

1. The folklore Bardwi Sikhla has a very special connection with relation to the tradtion and culture practiced by Bodos, the fact of which is less known to the people.
2. Lack of knowledge and interest about the folklore found in young generations. Moreover, young generation is mostly inclined towards western culture.
3. Through generations the folklore has been passed by oral tradition. It is seen that in the present context, the oral culture has been losing its ground in comparison to modern technology.

4. Bardwi Sikhla dance is one of the dance forms named after the Bardwi Sikhla follore, is performed by Bodo girls that has went on to become an element of community identity in national and international forum. No significant steps have been taken so far to preserve the folk traditions.

3.2 Discussion from the Group of Film Makers in Bodo Society

Discussions with local Filmmakers from BTAD, reviled more understanding and information about the Bodo Documentary production. The following information were gathered:

1. More Documentary films production with technology application is needed to be brought into market.
2. There is very less Documentary production in Bodo film industry.
3. No Documentary film is ever made on folklore Bardwi Sikhla.
4. People are progressing, they are in constant move. In such situation, traditions and culture have very little place. So Documentary can be the better medium to preserve ethnic tradition and culture of the community.
5. Though a few films documentary on social issues are there, no film is ever made on Bardwi Sikhla.

3.3 Information and Feedback Gathered from the Participants, Phase-I

The above information was gathered based on discussions and justified through survey on student volunteers of CIT and Kokrajhar Govt. College and other volunteers (Bodo and Non-Bodo origin). Analyzing the above views, survey was conducted. From the discussion it is also known that there is no full-length documentary specifically on Bardwi Sikhla except a few short videos archive in the digital media platform [12, 13]. However, there are Documentaries based on other social issues. A short edited video [14] was prepared from video clips collected from different online sources. The video presents some idea about folklore Bardwi Shikla an oral tradition of Bodo society. The video was shared and showcased online and offline to the student and feedback was gathered through Questionnaire form.

After the online and offline screening of the documentary, the core topics related to the aesthetics viewing experience were taken. Survey was based on six questionnaires. Details of questions summary are highlighted below:

The first question (Q-1) was asked to understand whether the volunteers know about Documentary film.

The second question (Q-2) was asked to if they knew about the folklore Bardwi Sikhla.

The third question (Q-3) was asked to learn if they have watch documentary film fully based on Bardwi Sikhla in any media platform.
The fourth question (Q-4) was to understand if visuals in the video support the story narrated or displayed about the Bardwi Sikhla.
The fifth question (Q-5) was to understand if the video expressed all the details about the concept of Bardwi Sikhla.
The last question (Q-6) was to understand if alternative techniques should be used to solve the limitations experienced in the video to develop better communication.

3.4 Feedback Gathered from the Participants, Phase-II

Based on the feedback from Phase-I, a short Documentary based on Bardwi Sikhla was prepared through two dimensional (2D) animation implementation with live-action [15]. In the beginning animation concept was developed as per the story (that include character, script, Character design and storyboard) for animation sequences. Live-action clip from different sources was used that would fit and useful to make the narrative clear.

Five students from B.Des. 6th semester from MCD department of CITK were involved in animation Production process. They were knowledgeable about design perception and also possessed fair knowledge of documentary filmmaking. The voice narration was recorded as per the script. The sound effect was taken from online as well as offline sources. Finally, following the plan as adopted in pre-production process the final film was edited and ready for exhibition.

The final film was again shared and showcased using both mode to the volunteers. Feedback was gathered through Questionnaire form. Survey was based on six questionnaires, intended to understand the potential of animation implementation to live-action Documentary. Details of questions summary are highlighted below:

The first question (Q-1) was asked to understand whether they know about the animation.
The second question (Q-2) was asked to if the animation used in the film have supported the concept of film to convey the information effectively.
The third question (Q-3) was asked to learn if animation as a tool can be useful to present oral tradition.
(Q-4) Desired to understand if animation application should be practiced more in tradition and cultural based Documentary films to preserve them, provided the authenticity of information remains intact.
(Q-5) Desired to understand if animation-having command to visually express finer aspects in details of the issues, can be useful to solve the limitations of live-action Documentary film and can create better communication.
The last question (Q-6) was to understand if producing more such animation with live-action documentary film can help in the upliftment of Bodo tradition and culture. The study design structure (Fig. 1), has been followed to identify the animation support to documentary film.

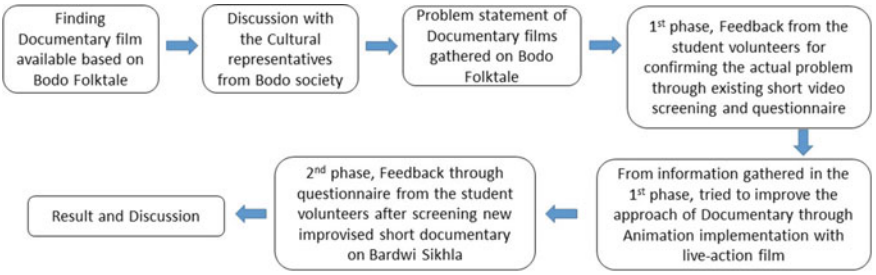

Fig. 1 Design study flow diagram

4 Results and Discussions

4.1 Participants' Responses from the Survey Done in the First Phase Are presented in Fig. 2

The first question (Q-1) was intended to know if the volunteers know about Documentary film. About 90% of them opted yes, that shows the majority of people knew about the Documentary film and 10% opted no. The second (Q-2) question aims to know if they knew about the Bodo folklore Bardwi Sikhla, wherein 45% knew about the tale and 55% of them didn't knew. Third question (Q-3) was intended to know if they have watch any Documentary film based on folklore Bardwi Sikhla in any media platform before, wherein 25% have watch documentary based on folklore Bardwi Sikhla and 75% of them have not watch. The fourth question (Q-4) was raised to know if the visuals in the video support the story narrated or displayed about the

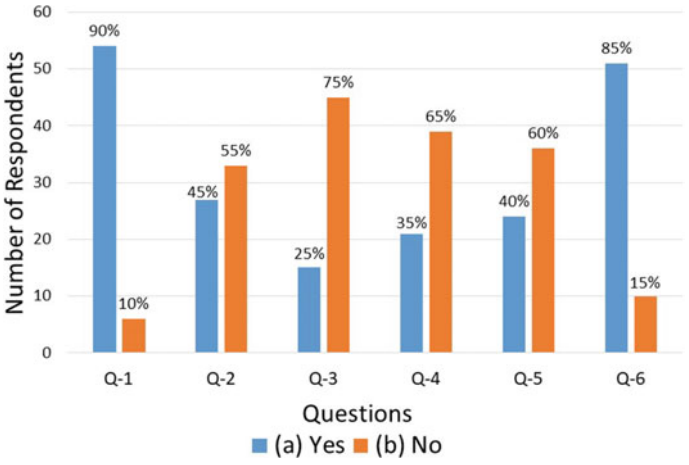

Fig. 2 Participants' responses against questions (Q1–Q6) mentioned in Sect. 4.1

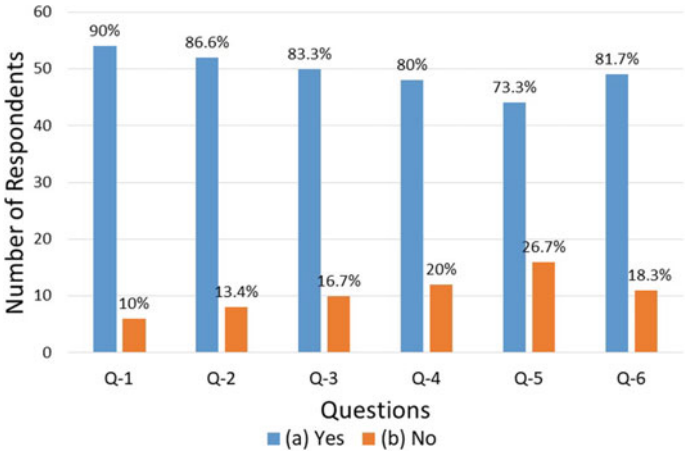

Fig. 3 Participants' responses against questions (Q-1 to Q-6) mentioned in Sect. 4.2

Bardwi Sikhla, where in 35% opted yes and 65% opted no. Fifth question (Q-5) was to understand if the video expressed all the details about the concept of Bardwi Sikhla, wherein 40% agreed and opted yes and 60% disaggred and opted no. Last question (Q-6) was intended to understand if alternative techniques should be used to solve the limitations experienced in the video to develop better communication, 85% of them opted yes and 15% of them opted no.

4.2 Participants' Responses from the Survey Done in the Second Phase Are Presented in Fig. 3

The first question (Q-1) was intended to know if the volunteers knew about the prospective of animation film. About 90% of them opted yes, that shows the majority of people knew about the animation film and 10% of them opted no. The second question (Q-2) aims to know if the animation used in the film have supported the concept of film to convey the information effectively, wherein 86.6% said yes and 13.4% of them said no. The third question (Q-3) was to know if animation can be a useful tool to present oral tradition, wherein 83.3% of them opted yes and 16.7% of tem opted no. The fourth question (Q-4) was raised to know if animation application with authentic information should be practiced more in Documentary films in order to preserve tradition and culture, 80% opted yes and 20% opted no. Fifth question (Q-5) was to know if animation can be used to solve the limitations of live-action documentary film to create better communication, wherein 73.3% answered yes and 26.7% answered no. The last question (Q-6) was to intended to know if more such animation production can help in the upliftment of Bodo tradition and culture, 81.7% of them opted yes and 18.3% of them opted no.

5 Conclusion

Tradition and cultural practices are the basic beauty and identity of any community. Throughout the history, it is passed on from one generation to another and it will be so transmitted in the same manner in the future. One way of achieving the purpose of preserving and transferring genuine tradition and culture is the proper documentary presentation. The practice of implementing animation in documentary film genre is not new and has been used to focus and highlight various issues in the past, but the real potential of the medium is still explored.

The documentary films have never been able to attract much viewers as compared to other genres. With the help of animation there is always a colossal possibility to create innovative contents those are unique, attractive and more informative. Animation makes any sort of difficult narratives more interesting and therefore, helps the audience to easily access the themes and understand the subject matter of a documentary film more effortlessly.

This paper examines the representation of the culture and tradition of a community in a documentary film using the methods of production process viz. the imaginative exploration of the real life objects and situations with the use of animation techniques. It surveys and comprehends if the same can be used to preserve culture and tradition of a community.

The paper highlights the representation of a folklore Bardwi Shikla which has been transmitted through oral tradition in a Bodo community. And it is seen that the participants of the experiment could comprehend the sentimental details described in the sample documentary film supported with animation. The sample film could convey the desired message and could reach to the populace across the community and to others as well. Based on feedback responses on the film after screening to users (both Bodo and non-Bodo origin volunteers), it is seen that animated illustration contents and voice-narration support in explaining some finer aspects that could not be shown through real life shooting and is significant for better communication.

Thus, the animation support documentary film is effective in communicating the finer issues, the sentimental details ascribed in a tradition and culture of a community, and the authentic and real knowledge about the tradition and culture is shared within the community and with others as well. A conclusion is drawn that a context specific animation support in digital documentary production could serve both as an archive and as well add on editing facility for flexibility and better expression of the content. The paper also suggests that if some principles in this context could be formulated, then it would enhance the documentary film making process in the future. And that the academic learning model of the same be structured to train students of Bachelor of Communication Design.

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Potential Benefits of Corporate Social Responsibility (CSR) in the Construction Industry

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Abstract Corporate social responsibility (CSR) is becoming more prominent as a core plan for the construction industry and its businesses, which is most likely motivated by two important quandaries that represent the construction industry's distinct characteristics. Various aspects of social well-being, such as cultural events, environmental, economic, and safety and health are influenced by construction activities and built facilities. According to the previous studies, being socially responsible enables construction companies to gain a long-term competitive advantage and improve operational efficiency from an industrial viewpoint. This paper intends to include a systematic review of CSR studies in order to recognize and actualize the potential for CSR implementation by construction sectors. The results have implication for construction companies' trending CSR activities in reaching their target of being socially responsible and improving competitive companies reward.

Keywords Corporate social responsibility · Construction · Benefits · Review · CSR

1 Introduction

Industries are likely to react to rising social and environmental problems resulting from corporate social responsibility (CSR) [1]. According to Lu et al. [2], the construction industry is not socially conscious and has a bad reputation [3]. Different construction operations, such as the manufacturing and transportation of raw materials, actual construction, and the process and use of building goods, all consume many resources and energy [4]. As a result, these activities impact the environment and ecosystem in air pollution, excessive dust, carbon, and greenhouse gas emissions [5]. Furthermore, construction activities are labor-intensive and have a high incidence of injury exposure. As a result, construction work is very unhealthy and

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dangerous for construction workers [6]. Hence, when it comes to CSR, the construction industry is considered to be behind many other industries [7]. One of the critical reasons for the unsatisfactory situation is a lack of innovative CSR research [8]. Despite the demands to enhance social performance, due to the fragmented and diverse nature of the sector, only a few construction firms have successfully transformed their businesses to become socially responsible [9]. According to Othman [10], creative and value-added strategies for improving CSR implementation in the construction industry should be investigated. Therefore, this paper aims to recognize and conceptualize the potential of CSR implementation in construction through literature study.

2 CSR in the Construction Sector

Depending on the scope of the connotation of CSR, authors interpret it more narrowly or broadly [6]. Theorists [e.g., 11] have stated that enterprises are required to optimize income considering the law and the ethical boundaries. According to Carroll [12], CSR with respect to a CSR theoretical framework can be defined as a pyramid, a pyramid in which CSR practices can be grouped into four types: discretionary obligation, ethical, legal and economic. From the current trend it is more evident that the perception of the society related to the companies is shifting towards the socially conscious goals rather than focusing on the legal and economic aspect [13]. According to Frankental [14], CSR can be constructed in various ways as culture and perceptions change. Dahlsrud [15] gathered 37 definitions of CSR from literatures and defined five dimensions of CSR, contributing to a better understanding of the concept. Even after decades of study, there is no mutual consensus on the explanation of what this principle generally is [4].

Researchers have used the stakeholder approach to explore effective CSR practices embedded in economic, environmental, and social dimensions [16]. Construction firms handle stakeholders' expectations to optimize values and profits from an economic point of view [17]. Construction companies use a mix of voluntary-based and mandatory-controlled CSR methods to find solutions to issues related to environmental closely associated with stakeholders' priorities [18]. Zhao et al. [4] classified CSR practices of construction enterprises into nine stakeholder categories: workers, owners, clients, suppliers and partners, local communities, government, competitors, non-governmental organizations (NGOs), and capital the environment by combining project-and corporate-level CSR practices. Jiang and Wong [6] sought to distinguish the respective quality and safety practices as a separate group, while Zhao et al. [4] viewed them as a sub-aspect of customer-related CSR practices.

3 Research Method

This review-based study aimed to discuss the CSR potential in the construction industry through literature. For relevant publications, first, an electronic search was carried out in the *Scopus* database. The following keywords were used to search literature published in *Scopus*:

TITLE-ABS-KEY ("corporate social responsibility" OR "corporate environmental responsibility" OR "sustainable responsibility" OR "corporate social performance" OR "construction" OR "construction management" OR "construction project management."

AND

"Construction industry").

Initially, 336 documents were included in the survey. Meanwhile, though the research on CSR in construction has increased since 2000 [19], this study limits the reach of journals from 2010 to 2019 to ensure more coverage and to obtain more publications as possible. Additionally, advanced search rules were set, including a document type of "Article," a source type of "Journals," and a language of "English." Only journal articles were chosen in this study because of their reliable source of knowledge [20]. Some articles use the word "corporate social responsibility" in the abstract; however, they do not focus on the potential of CSR in construction. Similar articles were excluded from the sample. After careful refinement, a total of 58 journal documents were extracted.

This study's results are presented based on the number of documents per year, articles per document source, and authors' keyword co-occurrence network. VOSviewer, a visualizing tool developed by Van Eck and Waltman [21], is used in this study to produce the co-occurrence network maps. Van Eck and Waltman [22] and Vigneshkumar and Salve [23] suggested that VOSviewer is more appropriate for visualizing large networks. The working mechanism of the VOSviewer tool can be found in [22].

4 Results

4.1 Distribution of Publications per Year

Figure 1 shows the annual number of selected articles with a trend of fluctuant growth since 2014. It can be seen that the number of publications released per year has gradually risen over the last 6 years, from ($n = 6$; 10.34%) in 2015 to ($n = 7$; 12.06%) in 2017, and ($n = 10$; 17.24%) in 2019.

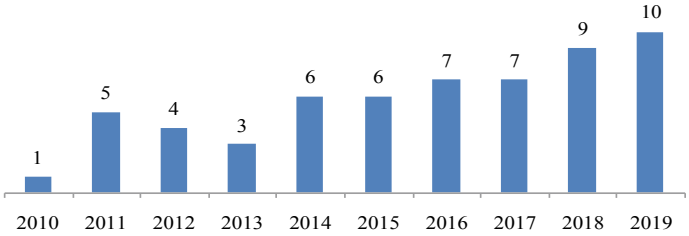

Fig. 1 Number of relevant articles published yearly from 2010 to 2019.

4.2 Distribution of Publications in Journals

Figure 2 lists top journals with high levels of aggregation of CSR articles. In terms of the number of papers published by the journal, the Journal of Cleaner Production has the most papers published for CSR. This is followed by the Construction Management and Economics, Journal of Engineering, Design and Technology, and International Journal of Construction Management. Overall, the core journals in CSR research are either interdisciplinary or multidisciplinary, indicating that CSR is an interdisciplinary or multidisciplinary science with elements from sustainable, environment, social sciences, management and many other domains.

Fig. 2 Distribution of influential selected journals, 2010–2019.

4.3 Potential benefits of CSR in Construction Sector base on Co-occurring Keywords

The core contents of the published documents are defined by the keywords [24], and so it is important to cluster the keywords into different themes to describing the concentration field for this present study. Initially, 173 keywords from retrieved documents were chosen, and by performing further analysis, keywords such as "corporate social responsibility," "CSR," "construction industry," and so on were removed. Finally, 30 influenced keywords have been chosen, which are visualized in Fig. 3. The connection lines in Fig. 3 represent the closeness among keyword pairs, and the font size denoted the frequency of keywords. For example, sustainability is the keyword that has been frequently used in retrieved articles that are closely related to the UK, which covers research focusing on comparing organizational strategies of UK and Turkey construction companies for economic sustainability [25]. The clustering of keywords into many groups is illustrated in Fig. 3. Keywords that belong to the same cluster have a higher co-occurrence rate. Figure 3 observations can lead to the following keyword cluster, which describes the mainstream research direction in CSR benefits:

Cluster 1—Culture: The culture and awareness of individual organizations can significantly impact whether and to what level CSR activities are implemented in organizations [26]. The term "organizational culture" refers to a diverse collection of assumptions, principles, symbols, and beliefs that characterize how companies

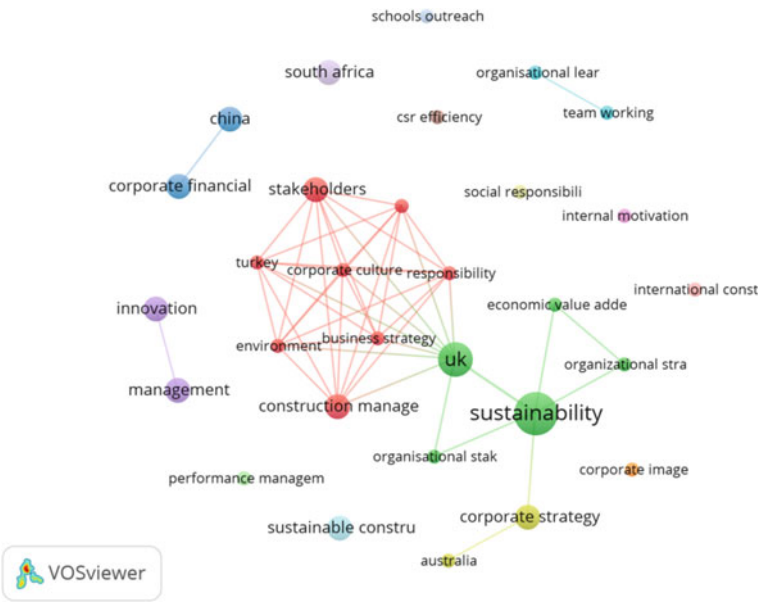

Fig. 3 Visualization of co-occurring author keywords

operate [27]. CSR activities' nature and main drivers can also be influenced by the individual values and principles of top executives and the leading founder [28]. Furthermore, according to Liang and Xue [29], individual organizations' "internal values" can result in a better CSR understanding along with the execution more than the impact of "external influence" on such activities. For the implication and execution of the CSR practices, construction companies could acquire and exchange the knowledge related to CSR from global, national, or local bodies and enhance the skills related to CSR through proper education and training [16].

Cluster 2—Reputation: Another purpose for CSR implementation is to boost the brand, credibility, and image of construction companies [4]. The public's overall view of a company is its brand image or credibility [8]. CSR is seen as a cost-effective way to create, build, and retain differentiated branding over time. Participating in CSR activities on a regular basis will help companies establish a reputation for being trustworthy and honest [30]. CSR involvement can also be used to target new customers and earn their loyalty [31]. According to the researchers, construction companies' reputation-building CSR efforts will improve partnerships with other practitioners in order to gain several opportunities in bid-winning, consequently leading to increase in profit [8, 16].

Cluster 3—Policy: Despite a paucity of evidence in the literature, government incentive programs are legitimate and successful ways to enhance the execution of sustainable construction practices [32]. For example, in response to mandatory policies, the Ghanaian government offers financial incentives to encourage CSR via tax breaks for educational scholarships, community development projects, charitable donations, and sports advancement [33]. To combat poverty in India, the government created various CSR policies as incentives to promote different partnerships in public and private sector along with an upsurge in the allocation of government funding for the underprivileged housing projects [34].

Cluster 4—Human resources: Another important factor in participating in CSR activities relevant to employees' needs is the human resource benefits [35]. According to Wu et al. [16], workplace-related CSR programs will help an organization compete for better human capital and boost employee engagement, loyalty, dedication, and productivity. Sustainable construction, for example, improves community well-being through a safe environment and society [36], high worker productivity and quality [35], and management capacity [37].

Cluster 5—Financial: While it is debatable whether or not CSR can improve corporate financial efficiency, the incentive for financial gain remains the primary impetus for CSR implementation for construction companies [38, 39]. In other words, if construction companies believe that CSR activities will help them financially, they will be more likely to adopt them. Improved performance by lower operating costs and increased sales and turnover are all possible financial benefits [39]. These motives are monetary since they result in economic benefits for the recipients [40]. For instance, in order to provide a promising opportunity for the prospective workers and fresh graduates so that they understand the system and effort required in adjusting to the workplace environment, three construction organizations in Taiwan formed partnerships with schools [41]. Next, though participating in CSR activities may

be expensive for companies [42], it can help businesses improve their corporate reputation and, as a result, increase sales and profits [8].

Cluster 6—Resources availability: Enterprises have more opportunities to provide goods effectively and economically and better meet consumer demands due to the greater availability of resources and capabilities [43, 44]. In case where construction professionals are capable of resolving the concerns related to social conscious like implementation of various schemes and optimization of various mechanisms for the environmental contamination incidents, their companies would be pushed and motivated to implement the CSR activities that are concerned with environment protection [6, 26].

Cluster 7—Supplier-induced: Construction companies should collaborate and establish long-term partnerships with green material suppliers to ensure the quality output of building materials [45]. These long-term partnership practices can contribute to the potential purchase and adoption of sustainable technological innovations at a reduced cost. Construction companies can have better options and fulfill consumer needs by using green building materials. Further collaboration with green material suppliers can potentially mitigate the risk in supply with the use of conventional materials (for instance, the rise in cost and the depreciation in the construction quality) [46].

5 Conclusion

This study focused on examining the potential benefits of CSR implementation by construction companies based on systematic literature analysis of 58 journal articles. According to the descriptive analysis, researchers are becoming more interested in CSR in construction companies. The benefits of CSR implementation represent the construction industry's inherent willingness and broad concerns. These are financial, reputation, human resource, supplier-induced, policy, culture and awareness, and resources. The research provides knowledge to construction companies and academicians through visualizing the CSR benefits for implementation in the construction industry. The current study was limited to selecting literature samples by extracting articles only from the Scopus database. In the future, other databases could be used to have a more comprehensive view of the research field by the selection of a large sample size.

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The Role of Postural Assessment Techniques in Different workplaces—A Review

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Abstract The struggle for the upsurge in productivity in industrial sector has become a necessity in present day's competitive world. The cut throat competitiveness has all the way come down from the latest machinery to the management of man with the machine. The management of human strength and psyche with respect to their working can lead to increased productivities. The wrong notion of squeezing out excessive work from workers has resulted in declined productivities. Industrials have now started realizing the need of the safe working environment for workers so as to bring feeling of security and belonging ness amongst the workers. Industries, being dynamic in nature should undergo periodic investigations so that any kind of health issue faced by workers could be located and resolved. In this paper, postural issues such as musculoskeletal disorders faced by workers have been discussed, and an overview of the postural assessment techniques, RULA and REBA has been presented. This work would serve as a guideline for the researchers who intend to study postural problems amongst workers.

Keywords RULA · REBA · Musculoskeletal · Disorders · Postures · Ergonomics

1 Introduction

1.1 Productivity

The efficiency in production is known to be the productivity i.e., amount of output obtained from a given set of inputs. Thus it is commonly expressed as an output-input ratio. There are several factors based upon which productivity can be categorized as Multi factor productivity and Single factor productivity [1].

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Multi factor productivity (MFP) measures the output against the combined inputs. The combined inputs consist of material, energy, labour or capital. MFP gives as idea of the overall performance of an industry.

Single-factor productivity (SFP) measures output per unit of a single resource input. Single resource input can be either of material, energy, labour or capital. The most common SFP is the labour productivity. Single-factor productivity levels are also influenced by the intensity of the usefulness of the other inputs.

The productivity measured with respect to the labor has a big role to play. If the labor is not comfortable with the job, then the output will be badly affected in two ways. Firstly, the factors such as absenteeism, reluctance, lame excuses, leaving the job, etc. will hamper the work and thus decrease in productivity. Secondly, heavy compensations paid to the workers on medical grounds again will cause a negative impact on the productivity. Thus ways and means shall be framed so that the worker feels safe and is comfortable with the assigned job. Researchers have been working out to develop newer techniques in order to enhance the productivity. The health problems faced by workers had been a major catalyst in affecting the overall performance of any industry. The identification of such problems much before they get exaggerated has been of great importance, and several industrial scientists have been exploring in this regime. Some of the very common techniques developed to study the musculoskeletal disorders are e Quick Exposure Check (QEC), the Ergonomic Workplace Analysis developed by the Finnish Institute of Occupational Health (FIOH), ACGIH's Hand Activity Level threshold limit values method (HAL), the Job Strain Index (JSI), the OCRA index, the EN 1005–3 standard, the Rapid Upper Limb Assessment (RULA) and the Rapid Entire Body Assessment (REBA). Amongst various health issues, Musculoskeletal disorders (MSDs) have been of great concern to ergonomists and scientists.

1.2 Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) are injuries caused to body structures such as tendons, muscles, joints, ligaments, nerves, bones, etc. [2]. The studies have revealed that MSDs resulted in severe long-term pain and physical disabilities. Millions of people are affected by MSDs, and they can cause issues in other regions of the body such as the back, neck, shoulders, elbows, forearms, wrists, and hands [3]. The presence of many techniques to study MSDs at times results in a conflict amongst the industrial engineers as which technique has to be used. Moreover, the usefulness of these existing techniques cannot be denied. Due to these very reasons, the authors found a strong purpose of writing this paper. Catering to all existing techniques in a single article makes it quite complex for the readers. Thus it was decided to review any two prevalent techniques which have been used to investigate MSDs. In this paper, the authors have attempted to bring forth the usefulness of two ergonomic techniques such as RULA, REBA. The past literature has been reviewed and the findings have been discussed in this article.

2 Literature Review

The literature review has been classified into certain subsections for the better understanding of the readers. Following sections discuss the importance of ergonomics in enhancing the productivity. Also the techniques RULA and REBA has been briefed in the subsections so that the readers get to know these techniques and thus understand the application of the same.

2.1 Ergonomics and Productivity

The negative impact on the productivity due to improper working conditions of workers can be worked out using Ergonomics. Ergonomics (or human factors) deals with design of the job or workspace in such a way so that the worker feels safe and comfortable while performing his/her job. It stresses upon the wellbeing of human beings while they are engaged in their respective jobs. Ergonomics basically focusses upon the occurrence of occupational injuries due to uneven postures and layouts. Thus it directly relates to the productivity and it has been observed by many researchers that safe working conditions motivate workers and thus a worker can give his/her best. There are guidelines developed by experts which clearly predict i) the odd postures and ii) layouts where a worker/ employee can work with his/her maximum speed. Ergonomics is also concerned with the weight lifted by the worker, work height, distance to be moved by the worker, total working hours, rest pauses, etc. [4–6]. Musculoskeletal disorder (MSD) take place amongst workers especially when manual lifting is performed by them. MSD's can be attributed to the maximum injuries taking place in industries. These may happen due to odd postures, repetitive motions and prolonged working hours [7]. According to the National Safety Council's (1992) Accident Facts, MSD's such as back injuries had been the reason for 32% of all worker compensation cases. Thus it becomes a necessity to reduce such disorders so that worker is safe and system becomes more productive [8]. A lot of work has been carried out to deal with MSD's and many techniques have been devised to check postural disorders and accordingly suggest the ways and means to rectify the odd ones. The techniques which have been used frequently at various working sites are RULA, REBA, NIOSH, OWAS [9].

The methods, RULA and REBA are applied on the elements of a task. The given task is divided into elements depicting motion of the different body limbs as per some defined criteria. After carrying out measurements of the individual movements, the results are integrated so as to obtain a single score for each body part. These individual scores are then summed up to obtain a single score which is further used to find the risk associated with the job.

Table 1 Rapid Upper Limb Assessment (RULA) details

Section A: arm and wrist analysis	**Section B**: neck and trunk analysis
• Lower and upper arm positions • Wrist position and wrist twist • Look up posture • Muscle use • Load/Force score, etc.	• Neck position • Trunk position • Legs use • Muscle use • Load/Force score, etc.

2.2 Rapid Upper Limb Assessment (RULA)

It is an assessment tool which considers postural loads and biomechanical criterion of the respective task on the upper extremities of the body such as neck, trunk, etc. Body postures, forces and repetition of work are evaluated and recorded on a single worksheet. Scores are awarded for different body regions as different sections: Section A for arm and wrist analysis and Section B for neck and trunk analysis. Once the data corresponding to section A and B is recorded, standard tables are used to compute risk factor variables and then calculate a single score depicting the level of MSD [10–12]. For example, if single score is (i) 1–2, there is no risk (ii) 3–4, there is low risk and (iii) 5–6, there is medium risk and (iv) 7 onwards indicates high risk. Table 1 shows the details to be recorded and evaluated under both sections.

2.3 Rapid Entire Body Assessment (REBA)

This is also an important ergonomic tool which makes use of a systematic methodology to assess whole body postural MSD's and risks associated with job tasks. Here, in this technique also, the data pertaining to different movements, repetition in task, couplings, body postures, etc. is recorded on a single worksheet and then evaluated. In REBA technique individual scores are given to different body parts such as shoulders, knees, legs, neck, elbows, wrists, forearms and back. Once the scores are awarded to each body section, then totaling of the scores is done to obtain a single score and thus single score will decide the severity in the MSD [13]. For example if single score is (i) 1, there is no risk, (ii) 2–3, there is low risk. (iii) 4–7, there is medium risk, (iv) 8–10 onwards indicates high risk and (v) 11 onwards indicates very high risk.

Table 2 shows the details to be recorded and evaluated under both sections.

Table 2 Rapid Entire Body Assessment (REBA) details

Section A: Neck, trunk and leg analysis	**Section B**: Arm and wrist analysis
• Neck position • Trunk position • Legs • Look up posture • Load/Force score, etc.	• Upper and lower arm position • Trunk position • Wrist position • Look up posture • Coupling type • Activity score, etc.

3 Methodology

The literature from the past has been reviewed only with a notion to find out the details relevant to postural assessment techniques namely RULA and REBA. The objective of the present work was to understand the usefulness of RULA and REBA techniques in determining the risk of work related musculoskeletal disorders amongst the persons involved in different jobs. The available literature mostly published in the years 2017–2020 have been reviewed and summarized in this paper. At some places, the literature from the previous years has also been used. Keywords such as musculoskeletal disorders, ergonomic techniques, RULA, REBA, safety, etc. were used to search various data bases. The literature has been organized in different paragraphs based upon the nature of the sector in which the said techniques have been applied.

4 Results/Discussions

4.1 RULA Technique

The RULA method was developed by McAtamney and Corlett in 1993. The main objective of RULA was to find out if workers were exposed to MSD risk factors in the upper extremities during the performance of their work. This technique have been found to be more sensitive as compared to many postural assessment techniques. The RULA method was applied to farm workers in order to assess postural problems faced by them, RULA along with the Nordic Musculoskeletal Questionnaire was used to investigate 861 farm workers in Thailand. The study revealed that majority of the workers employed for the past 10 years were facing MSD. Men were subjected to neck related problems and women were subjected to lower back related problems [14, 15]. On the same lines RULA was used for workers involved in blueberry harvesting, and MSD's in the workers were reported. However, the risk of MSD was taken care by using some machines for harvesting [16].

A study was carried out on138 farmers using RULA. All the farmers were involved in manual work. The study revealed that 71.4% of the farmers were subjected to low back pain. Apart from this, 62.1%, 56.4% and 55% of the farmers reported pain in fingers, shoulders and wrists respectively. The factors such as work experience, working hours, age, gender, etc. largely influenced MSDs and accordingly farmers were advised [17]. In a study the work carried out by 140 farmers of Rajasthan, India was investigated using RULA technique and Nordic Musculoskeletal Questionnaire technique. The findings have shown that 50% of the workers were facing MSDs particularly in the wrist, fingers, hands, and the lower back. The occurrence of these MSDs was associated with daily working hours, age, gender, hand dominant work, etc. A score of 5 was calculated using RULA in majority of the workers and accordingly directions were issued for further investigation [18]. RULA technique was been used by researchers to ergonomically improve the driver space of the agricultural tractor. In addition, 3D model was generated using Catia V5 software. The change in the design was ergonomically evaluated using RULA and other ergonomic tools [19]. The car seat was ergonomically designed using Catia software and checked for safe postures using RULA technique. The total score as per RULA was reduced from 4 to 2 which indicates that the worker would be safe and free from any postural disorder [20].

Low back pain amongst rubber tappers was investigated in the Chumporn Province of Southern Thailand. The study aimed at the ergonomic factors causing low back pain amongst the workers. Video filming was done to find various postures and then score were given as per RULA chart. The total score as per RULA sheet was 5.25 which pointed out the need for urgent medical investigation and thus revision in the postures or working style of the workers [21]. The workers involved in rubber tapping commonly are subjected to a MSD carpal tunnel syndrome (CTS). Factors such as wrist flexion mainly contribute to CTS. In total 268 workers were investigated, and workers were divided in two groups. One group was made to tap with the old knife and other group used the ergonomically designed knife for tapping. RULA technique was used to assess the wrist posture and it was found that the wrist postures were safe with the ergonomically designed knife [22].

The problems related to postural issues amongst ophthalmologists were also observed. The previous studies carried out on ophthalmologists have shown prevalence of 51–80% of MSDs The data shows that around 8% have to undergo surgery and 9% had to quit the work [23]. A study was carried out on 10 ophthalmologists from Queens University. The postures of the ophthalmologist while investigating the patients had an adverse impact of their skeletal structure. The RULA score was measured when ophthalmologists were carrying out their work with their previously followed practices. All the participants were then provided an educations module and asked to go through it and adopting the ergonomic rules as mentioned in the module should handle the equipment. The findings revealed a reduction in the score in the range of 2.10–2.77 resulting in less injuries. A decrease in Shoulder flexion and elbow abduction moments was also observed which paved way for a neutral body posture [24].

The workers carrying out wood chipping in forests were evaluated for biomechanical postures using RULA and other methods. The study revealed that RULA is the best technique for evaluating such work as majority of the workers were subjected to postural issues in upper limbs. The application of RULA showed to be more preventive than other techniques, as it gave a higher score value in each loading [25]. A study carried out on 10 workers of UKM Batik Jumputan Ibu Sejahtera Yogyakarta. The workers were involved in jobs like pattern making, colouring, dying, finishing, etc. The application of RULA technique revealed high risk of musculoskeletal disorders amongst the workers as the score obtained from RULA study was more than 7 [26].

4.2 REBA Technique

The Rapid Entire Body Assessment (REBA) method has been established by Dr. Sue Hignett and Dr. Lynn McAtamney, ergonomists from University of Nottingham in England. The REBA method has been considered to be the only method which is capable of pointing out the most uncomfortable postures such as squatting, sitting on the ground, lumbar flexion greater than 90° and torso twisting [27]. The occurrence of MSDs due to postural stress in female workers involved in uprooting job of rice cultivation were considered for investigation. REBA technique along with other techniques were used in thus study. The investigation was carried out on 166 female workers and a scale was used from 1 to 10, 1 indicated no postural problem and 10 indicated severe MSD issues. The study revealed several MSD issues amongst the workers especially in hip, wrist, knees, shoulder and lumber. It was suggested that proper rest pauses, proper postures, redesigning of tools, etc. should be adopted and workers should be trained to adopt safe working postures [28]. In olive farming, REBA and other techniques were used to assess the risk involved while carrying out pruning with chainsaw. The researchers suggested urgent changes in the style of working so as to safe guard workers [29].

The study was conducted on 15 workers engaged in small scale industry situated at MIDC Wardha (Maharashtra, India). Video filming was done and selected photos were cropped for analyzing the postures. Ergointelligence software was used to calculate the RULA AND REBA score. RULA was used for upper limb postures and REBA was used for analyzing whole body postures. As per RULA 43% of the employees were medium risk. On the other side, REBA have shown that 13% of the employees were under low risk but 53% of the employees were at higher risk as their REBA score was in the range of 8–10. The study thus suggested ergonomic improvements in the postures of the workers and accordingly organized training programs [30].

REBA technique was used for 40 jobs in an engine oil company and the results were correlated with Quick Exposure Check (QEC) technique. Highly trained health practitioners conducted the study. The study revealed that (i) with REBA 15% of the postures were at low risk, 60% at moderate risk and 25% at high risk and (ii) with

QEC 20% of the postures were at low risk, 50% at moderate risk and 30% at high risk. The results have shown a strong correlation between REBA and QEC analysis [31]. 673 workers (355 were males and 318 were females) were investigated for work related MSDs in Tehran Pars-electric factory to prevent inducing WMSDs. Since whole body of the workers was involved in doing work, thus REBA technique was used to determine the risk of MSDs. Nordic musculoskeletal questionnaire (NMQ) was the tool used to ascertain the prevalence of entire body disorders. The REBA was carried out on all the workers and the results have shown an action score ranging from 2 to 12. The prevalence of disorders in wrists, lower arms, upper arms, neck, trunk and legs were 90%, 79%, 70.1%, 51.3%, 36.1% and 60% respectively. Thus it was suggested that proper ergonomic measures should be taken on urgent basis in order to safe guard workers [32].

The risk of postural disorders in dentists was investigated using REBA technique. A study was conducted to investigate the postural issues of 48 persons in dental profession in Iran. The investigation was conducted using REBA technique. The occurrence of MSDs was ensured from Nordic Musculoskeletal Questionnaire (NMQ). The outcome of the study revealed that persons having disorders in the neck, back, shoulders and wrist were 65%, 60%, 38% and 31% respectively. The prevalence of the back disorders was more in woman than man. Thus improvement in postures and work conditions was suggested by the experts [33]. Ninety dentists were selected for the study. The findings revealed that 90% of the dentists were having postural issues and REBA rating was from moderate to high risk. The periodontists, oral surgeons, periodontists and maxillofacial were subjected to high risk levels. Thus proper layout and ergonomic principles must be incorporated and accordingly dentists must be trained. In fact, the ergonomic induced postures should be made as a part of curriculum in various Universities [34]. The dental professionals working in North Khorsan were investigated for MSDs using REBA technique. Sixty professionals were considered for this study. The occurrence of MSDs was confirmed from Nordic questionnaire. From the results it was concluded that 78.3% of the dentists were subjected to average risk level and 21.7% were subjected to high risk levels. Amongst all professionals, higher disorders were observed amongst woman. The results demand revised work procedures so that postural issues are resolved [35]. Using REBA technique, moderate risk was observed in 86% of the dental students in Bushehr University of Medical Sciences, Bushehr, Iran, and accordingly training programs were suggested where students would be trained to perform their job with safe postures [36].

In a study carried out on 40 orthotists and prosthetists, the prevalence of MSDS were assessed using Nordic Questionnaire and REBA technique. Ten working postures were evaluated for each orthotist and prosthetist. The results have shown that 55.6% of men and 47% of women amongst orthotists were subjected to pain in lower limbs, trunk and neck where as 74.1% men and 45.5% woman suffered from pain in upper limbs. Amongst prosthetists, no high risk was reported. A score of 4 to 7 was reported almost in half of the tasks, thus indicating medium scale risk and demand for corrective action. Thus the incorporation of ergonomic principles

Table 3 Summary of the RULA and REBA applied sectors and places

Technique	Sector	Place	References
RULA	Farm workers, Blueberry harvesting, Agriculture tractor, Car sear design, Rubber tapping, ophthalmologists, Wood chirping	Thailand, India, Yogyakarta	[14–26]
REBA	Rice cultivation, Olive farming, Small scale industry, Engine oil industry, Electric factory, Dental professional	Thailand, India, Tehran, Iran, Khorsan	[27–38]

in training modules were advised [37]. REBA technique has been used in conjunction with other techniques such as RULA, OWAS and remarkable results have been obtained [38].

Table 3 summarizes different sectors and different places at which the RULA and REBA techniques have been used.

5 Conclusions and Implications

There are several techniques developed by researchers and scientists for determining the work related musculoskeletal disorders. The issue of musculoskeletal disorders has become a matter of great concern for researchers. RULA and REBA techniques were widely used for assessing the risk of disorders. RULA is used for assessing disorders in upper limbs and REBA is used for assessing the disorders in entire body. These techniques can be used at places where manual work is involved may be in industries, hospitals, barber shops, dental professionals, ophthalmologists, etc. The studies conducted at various sites using RULA and REBA had revealed that there are several postural issues faced by workers/employees. The integrated score determined from these techniques reflected the risk of musculoskeletal disorders amongst workers/employees. The level of risk in majority of the cases was 'moderate to high' which is a serious issue, and if these issues are not addressed, they would result in decreased productivities. The suggestions given by the experts are quite simple and can be implemented without any difficulties. The revision in the style of working so that workers are ergonomically safe is the priority, and the new methods of doing work must be inculcated amongst employees through mandatory training programs. The implications of the RULA and REBA is to improve human interaction with the systems at different workplaces. The working environment involving human interaction can be improved and systems made more productive.

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User-Centered Non-suburban Indian Passenger Train

Archana and Amaltas Khan

Abstract Indian trains are the commonly used mode of commute in the country. Indian Railways being the sole provider of train commute caters to 22.15 million passengers via passenger trains daily. LHB (Linke-Hofmann-Busch) coaches of Indian trains are mainly categorized as Sleeper, 3 AC, 2 AC, and 1 AC coaches, where the predetermined standards are contemplated in lower, upper, and middle berths. The authors intend to study the berth width of LHB coaches of non-suburban passenger trains regarding pregnant women. It has been studied that passengers with diverse dynamics and anthropometric variables find it difficult to adapt the same. This research aims to study the berth standards, and ergonomic concerns of intended passengers, through literature study, observations, and surveys. The following research examines relevant ergonomic factors, which can be considered in scheming the berth with suitable width. Further to this results are drawn and discussed from the study to formulate the conclusion.

Keywords Adaptability · Berth width · Commute · Ergonomics · Inclusive · Trains

1 Introduction

In India, the railway plays a vital role as mass passenger public transport, which is economically sustainable to the majority of the population. Indian railway (further referred to as IR) maintains the rail network route, which runs 67,956 km in length, and is the fourth-largest rail matrix in the world as of 30th March 2020. Indian Railways being the primary mode of commute, carried around 8 million passengers and contributed to the transportation of 1.21 billion tons of freight in the year 2020 [1].

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It runs passenger trains on shorter routes as suburban trains and longer routes as non-suburban trains. Two types of coach designs are used by Railways in non-suburb trains, i.e. Integral Coach Factory (further referred to as ICF coaches) and Linke Hofmann Busch (further referred to as LHB coaches). Due to various limitations such as speed potential, poor riding comfort, heavy corrosion, and absence of safety features, the production of ICF coaches has stopped in 2018 and is to be replaced by technologically advanced LHB coaches in the interest of passenger safety and comfort [2, 3, 4]. In 2002, IR introduced LHB passenger coaches in India for the first time that was developed by Linke-Hofmann-Busch of Germany [5]. The coaches are designed with all the necessary features like high operation speed, lighter weight, higher passenger capacity, anti-telescopic (do not flip in case of collision), efficient braking system, improved modular interiors, advanced suspension system, and less noise level [6, 7].

In 1957, Research Design and Standards Organization (RDSO) was established under the Ministry of Railways at Lucknow, to develop and coordinate the design, standard, and specifications amongst various railway systems of India. The adaptation and maintenance of new LHB coaches are done by the same organization. The coaches are categorized into four classes i.e. General, Sleeper, 3 Class Air Conditioned (further referred to as 3 AC), 2 Class Air Conditioned (further referred to as 2 AC), and 1st Class Air Conditioned (further referred to as 1 AC) coaches. The berths in each coach have standardized sizes for the optimization of passenger accommodation.

The author aims to study the dynamics of passengers traveling through the non-suburban trains who use the mentioned coaches for long-distance journeys and face difficulty in adapting the standard seat width. The richness of the Indian context draws a heterogeneous mix of people which has been identified through observation studies. The group is further classified based on the interviews during the site study, which are pregnant women, obese passengers, and parents traveling with children (age below five years, no fare and berth allowed, exceptions are for voluntary cases) [8]. The author intends to focus and study one user group and orient this research towards pregnant women to study their concerns, expectations, and interaction with the berth. The standard berths provided across coaches do not accommodate the physiological consideration and mobility safety of the end-users.

2 Methodology

Ergonomics is an essential component of a successful design, in the case of identified user group' it plays a vital role in a comfortable and safe journey. The literature review is conducted to understand the standards followed in berth facilities and provisions for pregnant women in non-suburban trains. To analyze the intended users the relevant data such as sleep patterns, sleeping position, and anthropometric data has been studied through literature review, survey, and case studies. The data

is further analyzed through mapping and results are drawn and discussed preceding conclusion.

3 Variables of the Train Journey

The Sustainable Development Goals 2030 calls attention to sustainable and inclusive cities. It also stresses providing accessible and sustainable transport systems for all the citizens. Intending the accessible travel commute through rails in the non-suburban train is essential [9]. Considering the number of passengers traveling by the long routes it becomes very essential to appraise the comfortable berth for all the users including those who have special needs. In the interest of safety and comfort of the following passengers, Senior Citizens, Female passengers of'45 age or above', and Pregnant Women, there are 2 lower berths reserved in every Sleeper, 3 AC, and 2 AC coach [10]. The following research reviews the Lower berth of the proposed LBH coaches as these coaches are planned to replace ICF coaches and run on all the rail routes in near future [3, 4]. The research is designed to study the spatial need of pregnant women through their posture engagement in resting (sleeping and sequential postures) on the berth.

3.1 Sleeping Accommodation

Provision for a berth in 2 AC coach is provided in 2 T (Two-Tier), within each coach these tiers are composed in one bay. One bay comprises 2 lower berths, 2 upper berths are located in the longitudinal direction and one side lower and side upper berth is placed in the transverse direction to the coach Re (Fig. 1). Whereas in Sleeper and 3 AC Coaches, the berth is classified as 3 T (Three tiers), each bay comprises of two lower, middle, and upper berths each, in the longitudinal direction and one side lower, and side upper in the transverse direction to the coach Re (Fig. 1).

4 Contextual Studies

To understand the interaction of pregnant women (intended users) with the accommodation facility in coaches, contextual observations are conducted with intended group of users. The observations study is conducted in one to three-night duration journey on different routes of IR. IR has reserved two lower berths for the inclusive passenger including pregnant women, in the following coaches, Sleeper, 3 AC, and 2 AC [10]. The berth width in LHB coaches ranges from 610 to 665 mm, whereas the range varied from 480 to 550 mm in ICF coaches Re (Fig. 1) [11]. The study considered the inclusive interaction of the user with both types of coaches (LHB

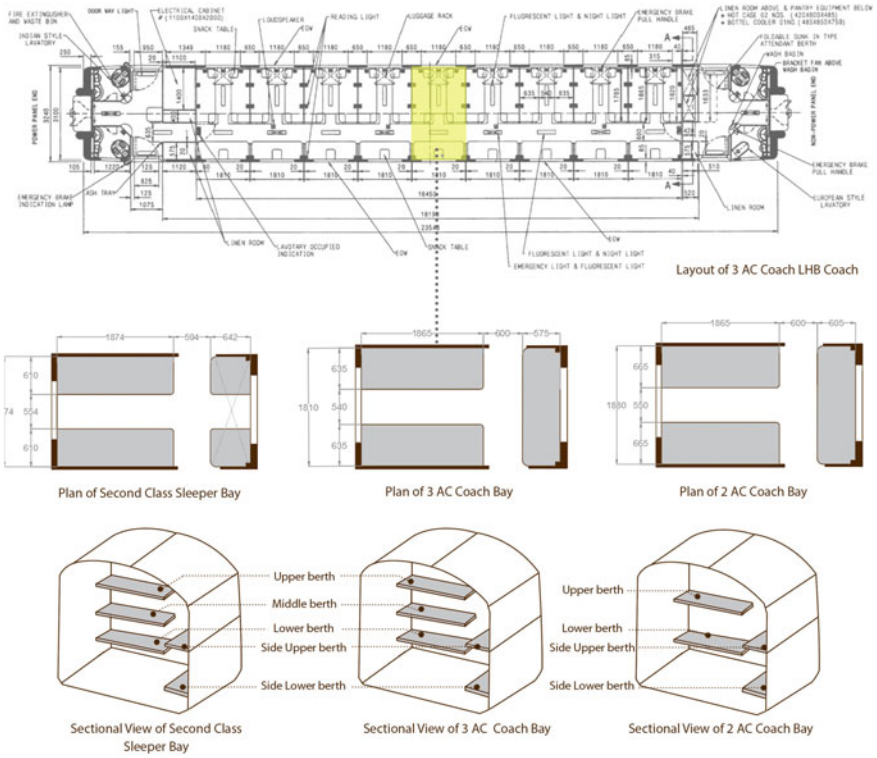

Fig. 1 Standard berth dimensions of one bay of the Sleeper, 3 AC, and 2 AC LHB coach [1], representation by the author

and ICF) as they are actively facilitating the Indian passengers to date. The study further assesses the insights collected through the reserved berth i.e. lower berth of LHB coaches as these coaches will be the future of Indian trains and have more berth width compared to ICF coaches [4].

Literature reviews have been conducted through articles, research papers, and guidelines by WHO to understand the physiological changes, sleep patterns, sleep disturbances, and categorization of BMI. A survey with a structured questionnaire has been used to examine 35 samples of Indian women who had prior experience of non-sub-urban train travel during pregnancy. The questionnaire is framed to study travel frequency, trimester, sleeping pattern during pregnancy and to collect anthropometric data, i.e. BMI before pregnancy. Using the insights collected through literature reviews and surveys, four sample sizes are identified based on the BMI category. Considering the studied sleeping position of the user, anthropometric data has been collected which is mapped on the reserved berth of Sleeper, 3 AC, and 2 AC, LHB coaches and synthesized further through result and discussions. The study is then encapsulated in the conclusion with a comprehensive overview of the identified concern.

5 User Study and Related Variables

Sleeping berth accommodation was introduced in trains in 1830 for the first time to ensure a comfortable journey since long routes can be very hectic without sleep and still doing successfully as it broadens the horizon of train travel [12]. Building on the same, the study explores granularity of the concerns surfaced by pregnant women through an online survey which intends to get relevant data such as pre-pregnancy Body Mass Index (further referred to as BMI), sleep compatibility on the berth, and factors to be taken into consideration for a better sleep experience.

5.1 Sleep Pattern

Women face various hormonal, and physiological changes during pregnancy, due to which it's very difficult to sleep comfortably in any position [13]. The most common disorders associated with sleep are sleeplessness, restless legs syndrome, sleep breath alterations and are more prevalent towards the third trimester [14, 15]. Sleep quality and comfort are very essential for the overall development of the fetus. It has been studied that due to biological changes pregnant women experience poor quality of sleep, night awakening, Insomnia, Sleep-breath alterations [16]. In the third trimester, the sleep disturbance rate is comparatively higher as compared to the first and second trimester [17]. Considering the sleep pattern it is very essential to ensure a comfortable and safe sleep facility for the user in train travel.

5.2 Sleeping Position

The usual sleep position of pregnant women changes due to the physiological body changes and increasing waist circumference from the first trimester to the third trimester. A survey conducted across 35 respondents shows that 87% of the women find side-lying as the comfortable position to sleep and further reconfirmed by the medical studies [18]. A side-lying position with legs slightly tugged up towards the chin is an ideal position for sleep to improve better blood circulation and nutrient's synthesis [19].

The side-lying position is considered for further studying and mapping as this is the most comfortable position of sleep during pregnancy. To classify the sample, anthropometric data has been collected as per the BMI category given by WHO.

	Height	Weight (Kg) (pre-pregnancy	Weight (Kg) third trimester	BMI	Permissible weight gain	Waist depth (from shoulders)	Folded knee depth (from shoulders)	Height (after tucking knees)	Ideal Width (getting up and down the bed)
Underweight	1580	44	55	17.7	12 (12.5-18)	522	540	1420	610
Normal Weight	1590	53	66	20.9	13 (11.5-16)	543	562	1450	645
Over weight	1540	62	72	26.1	10 (7-11.5)	556	572	1440	685
Obese	1530	72.5	81	30.9	8.5 (5-9)	567	591	1410	725

Fig. 2 Anthropometric studies are conducted in the 3rd Trimester of the user, which gives the maximum static width in millimeters, necessary for sleeping i.e. the width of the waist from the shoulder and knees from the shoulder

5.3 BMI of Users

In the context of a train berth, the intended passenger is divided into four categories based on the recommended BMI by the Institute of Medical and National Council Report i.e. Underweight, Normal Weight, Over Weight, and Obese (pre-pregnancy), and third-trimester gestational weight [20]. The pre-pregnancy body weights and heights of the samples are studied and BMI is calculated to understand the dynamics of categories across sample size. As per the sample collection across 35 Indian women, 37% were overweight, 32% normal weight, 17% underweight, and 14% obese before pregnancy.

6 Mapping

Based on four BMI categories (pre-pregnancy), four samples are studied and relevant anthropometric data is collected for posture profile. The measurements are taken in a side-lying posture when the user was in the third trimester of the pregnancy to widen the scope of the study Re (Fig. 2).

The collected data was mapped on the berths of three identified coaches. Considering the lower berth reservation for pregnant women, "the berth sizes studied in Fig. 1" are used for mapping the body position of the intended passengers [10]. The maximal width in side lying position is considered for the mapping i.e. "waist depth and knee depth from the shoulder and mapped in Fig. 3" shown below [19].

7 Results and Discussions

The results comprise the ergonomic factors required for pregnant women in reserved berth of Sleeper, 3AC and 2 AC coaches. This paper analyzes the sleeping provision for intended users while traveling in long route trains i.e. non-suburban trains. The anthropometric measurements were studied in side lying position and the related

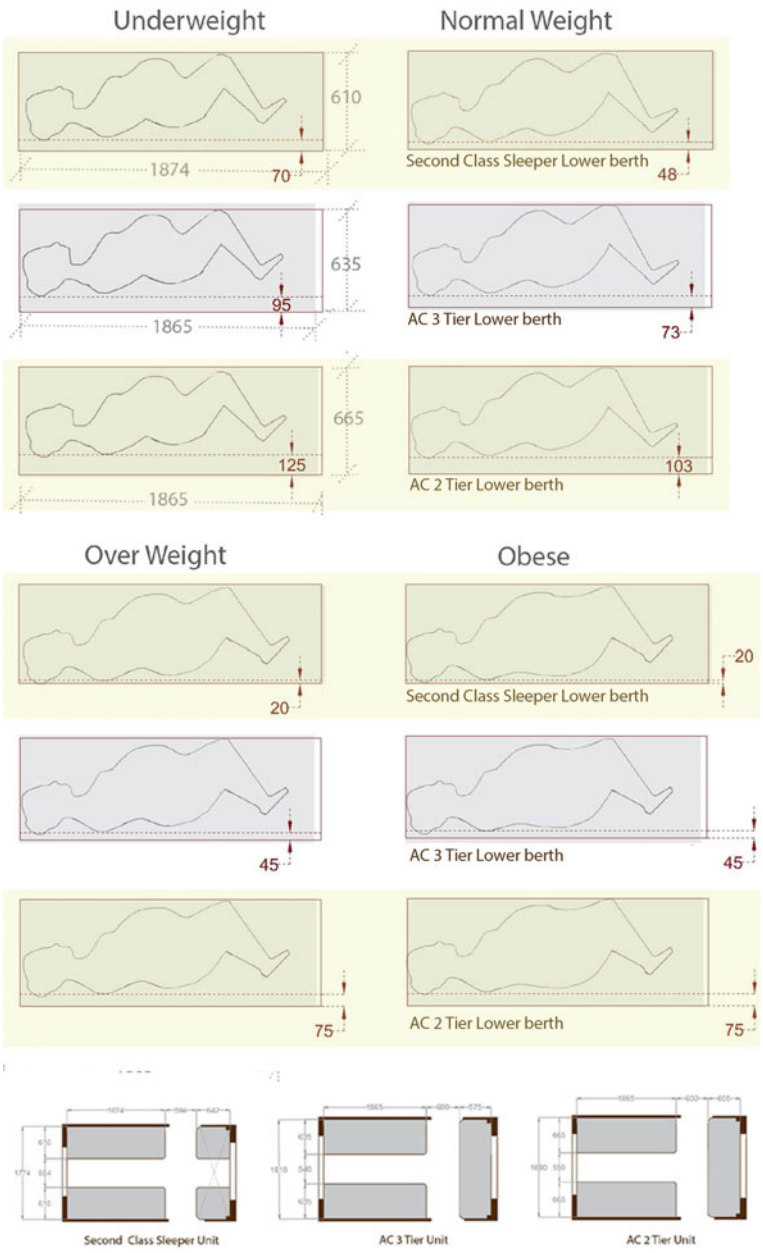

Fig. 3 Shows the measured body position of 4 pregnant women and mapped on the berths of Sleeper, 3AC, and 2AC LHB coach

	Sleeper (610 mm)	2 AC (635 mm)	3 AC (665 mm)
Underweight (610)	0 mm	25 mm	55 mm
Normal Weight (645)	35 mm	10 mm	25 mm
Over weight (685)	75 mm	50 mm	20 mm
Obese (725)	115 mm	90 mm	60 mm

Fig. 4 Additional berth width required by four BMI categories with refrence to the all three LHB coaches

sequential postures. The data is collected in third trimesters of pregnancy and respondents arising from four BMI specified by WHO.

Sleeping position and getting up from the same is difficult in pregnancy and needs extra attention. As per the survey conducted with 35 respondents, 90% of them found that to get out of lying position, the user needs to raise the upper body with the arms and hands to a sitting position, then gradually move legs over the side of the berth. Required width for the identified categories for getting up and down to the bed ranges from 610 to 725 mm, whereas the provided width ranges from 610 to 665 mm in specified coaches.

The above result reflects that the provided berth does not allow extra margin required to get down, and up from lying position Re (Fig. 4). Getting down or up from the bed is a struggle as it demands the body to use the arms and leg support, which in turn needs extra space to keep the entire body steady. The above results shows that berth of each coach needs extra width to accommodate comfortable required posture for identified categories of the intended user.

8 Implications

In Indian trains, the reservation ensures two lower berths for pregnant women in Sleeper, 2 AC, and 3 AC coaches, however, the berth sizes do not correspond to the user's requirements. The standards followed for the reserved berth of LHB coaches range from 610 to 665 mm berth, and is not sufficient for the user Re (Fig. 4). The same can be revised to accommodate the ergonomic standards required for the intended user. Design can play a salient role in accommodating the required sizes for the reserved berth without changing the bay size. Considering the future replacement of ICF coaches with LHB coaches, there is tremendous scope in making the new coaches inclusive and user-friendly.

9 Conclusion

Public transport is designed to keep every aspect of users in mind to provide an effective, efficient, and comfortable service and experience. Being a developing nation our population depends more on rail transport for commuting and has the scope of improvement.

The studied input is one variable that can improve the comfort and safety of pregnant women while traveling via non-suburban trains. Pregnant women go through tremendous physiological changes and respond to the standard berth provided in the trains differently. Their needs and expectations are different from the standard users considered for implementing the berth and the associated components. The consideration of the studied input in design and policies will make a huge difference as the LHB coaches are still in process of getting a widespread hold on Indian Railways. This brings scope for the designer and other relevant stakeholders to present a user-centric model of public transport for Indian users.

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Assessment of Construction Workers' Musculoskeletal Disorders Risk Using Quick Exposure Check Tool

Abhishek Trivedi, Parth Patel, Shail Pratap Singh, and D. A. Patel

Abstract The Indian construction sector provides employment to approximately 51 million people. It is the second-largest employer after the agriculture sector. However, the construction sector is the most hazardous sector across the globe. On average, 38 fatal accidents are reported daily in Indian construction. The main reason behind such a high accident rate is because most of the workers are illiterate, semi-skilled, or unskilled and temporarily migrated. Most of them do not have a quality of life, and they work 12 h a day at their workplaces. Construction workers experience a high level of stress and suffer from musculoskeletal disorders (MSDs) during or after leaving their jobs. They have complaints about lower back pain, shoulder pain, which reduce their productivity. In this connection, this study attempts to assess the exposure to risks related to MSDs of construction workers by using the tool-Quick Exposure Check (QEC). The QEC tool has been referred for preparing the questionnaire. 75 construction workers involved in various activities were interviewed based upon a prepared questionnaire. Their responses are used to obtain QEC scores of multiple activities. The findings suggest that activities related to Centering & Shuttering reported the highest QEC scores, indicating that the activities were the primary cause of severe MSDs. Shoulder and back had the highest exposure to MSDs. A fishbone diagram was prepared to discuss the root causes behind the issues. The work environment on-site can be made more suitable using ergonomic interventions to reduce MSDs in workers.

Keywords Musculoskeletal disorders (MSDs) · Ergonomics · Construction · Quick exposure check (QEC)

1 Introduction

The Indian construction sector is the second largest employer in India after the agriculture sector. The demand for basic infrastructure increases with the exponential

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increase in the population, thereby boosting the Indian construction sector. It accounts for 9% of India's GDP [1]. It employs a total of 51 million people having a total market value of around USD 5 billion. Moreover, it also involves risks of injuries and hazards because of the continuous use of machinery and power tools on scaffoldings at elevated levels. These activities pertain constant threats to people working on site [2]. On an average, 38 fatal accidents per day occur in the Indian Construction sector [3].

In developing countries like India, where the construction sector is unorganized and labor is cheap, less focus is given to worker's safety and well-being. Apart from this, most Indian construction workers lack respective skills, proper training and are prone to exploitation. Therefore, workers' stress level is high, and the performance level gets reduced. Due to lack of training, workers ignore the scientific approach to perform their tasks which involves handling heavy material and equipment, working on heights, lifting heavy weights, etc. They are also exposed to the harsh climate, dust, dirt, and toxic chemicals. All these factors cause the Musculo-Skeletal Disorders (MSDs) in workers' bodies. Ergonomic studies can help firms to take appropriate preventive measures to control MSDs suffered by construction workers.

According to the International Ergonomics Association (IEA) Council, "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design to optimize human well-being and overall system performance" [4]. The ergonomic intervention was found to be necessary to prevent MSDs among construction workers [5]. Quick Exposure Check (QEC) tool is an effective and practical tool to measure the exposure to risks in the construction sector causing MSDs. The concept of Fishbone Diagram (Root-Cause Analysis) is used to find the causes and severity of risk exposures in MSDs. An attempt has been made to improve the quality of life of laborers to increase productivity on site. The present study aims to measure the exposure level of workers in various construction activities.

2 Literature Review

This study focuses on the concepts of construction ergonomics, postures of workers during their jobs, QEC, risk exposures, and their classification related to various activities. Most of the construction activities involve the continuous movement of body parts, leading to pain and disorders in workers. Also, the environment on-site includes strict time frames and exposure to unanticipated hazards. Such stressful site conditions impart degradation at psychological, physical, and social levels [2].

To address the issues related to physical distress, past studies have conducted the postural analysis of various construction activities such as granite cutting, brickwork, shuttering, plastering, and material transportation, and it revealed that MSDs occur in four main parts of the body: shoulder, knees, back, and legs [6]. It was also observed that every four out of five construction workers have issues related to MSDs [7].

Carpenters, masons, and reinforcement workers reported lower back pain as major MSD, as they carry heavyweights, which vary from 15 to 50 kg [2, 8]. Further, carpenters also have pain in the wrist, hand, knee, neck, and shoulder [2, 8]. Lower back pain was found as a significant MSD among construction workers (40.64%), followed by shoulder pain (30%) and pain in the wrist and hand (24.19%). The study suggested that the age of the workers was a cause of developing MSDs. Work hours/day neither caused the MSDs nor impacted the Quality of Life (QoL) among workers [2, 8].

Manual material handling is also one of the major causes of MSDs in workers. It involves improper body postures, repetitive tasks, lifting heavy weights, etc. Past studies have identified critically affected joints through 'Aerial Performance Analysis System (APAS)' to analyze the linear and angular acceleration in joints. Due to repetitive loading actions, spine stability is lost, which ultimately results in MSDs [9].

Centre for Construction Research and Training (2008) reported that 37% of all injuries resulting in a day in the USA were related to strains and sprains, post completion of jobs. Studies related to construction ergonomics found that low severity incidents are observed to be included in most of the construction-related claims. Many of these are not 'Occupational Safety and Health Administration (OSHA) recordable'; hence, do not reflect in the Bureau of Labor Statistics. As far as formwork-related activities are concerned, struck by overexertion and exposure to harmful substances are the most riskier activities. A safety research study can help companies to identify risk exposure levels of various activities by preparing efficient safety measures to reduce the impacts of such risks on workers, thereby improving the quality of work performed [10]. Risk quantification explains the frequency, severity, and exposure involved in a particular activity [11, 12]. The average number of events per unit time is defined as the frequency. The magnitude of possible outcomes of that event is severity. The time duration during which a worker works in a hazardous situation is termed exposure. Frequency is termed in incident rates; how much impact is on the worker is the extent of severity, and exposure is defined in a unit of time. The combination of frequency and severity should be considered simultaneously to assess injuries and MSDs [11].

MSDs are the leading causes of lost work time, substantial illness, and reduced worker efficiency. The presence of MSDs points out towards the system failure, indicating a lack of suitable safety measures on-site. Many developed countries have a safety policy that no person/labor should fall ill due to work. Thus, while addressing the MSDs, the focus should be on the improved working environment, organizational structure, effective use of available technology, and monitoring the working environment [13]. QEC can act as a tool providing a basis for ergonomic interventions by assessing risk exposure levels for MSDs. It is a kind of observational tool used mainly by Occupational Health and Safety (OSH) practitioners. Four main parts of the body (viz. back, shoulder, wrist, and neck) are assessed by QEC [14].

To reduce the external load on a worker's body for transporting materials, conveyor belts or trolleys can be used [6]. Other measures to reduce MSDs could be by arranging regular check-ups and training considering workers' health and safety,

mandating the use of Personal Protective Equipment (PPE), and monitoring over time (40% of workers were working 4 h extra each day) [5]. MSDs can be prevented by identifying ergonomic intervention, commitment from top management, worker's involvement, regular risk assessment, prevention measures, and proper training [13]. Researchers have also developed few other models to study the risks involved due to various construction activities. It helps the contractors know about the major safety risks involved to take precautions beforehand. Assessment involves the inclusion of various activities and components that could cause hazards, ultimately leading to MSDs. The risk scores obtained from such models helps in proposing the remedies for the identified construction risks [12].

3 Objectives

Based on the literature review carried out, the following objectives are set:

1. To carry out an ergonomic survey of construction workers,
2. To evaluate exposure risks of workers,
3. To assess risk exposures to MSDs of construction workers using the QEC tool.

4 Methodology

4.1 Details About the QEC Questionnaire

QEC, being an observational tool, requires data to be input to get quantifiable observations. Ergonomic survey of labors was carried out for the same.

The surveys for the study were done on the ongoing sites in the cities of Ahmedabad, Surat, and Warangal in India. The workers were informed about the survey and were interviewed in the local language. Risk exposure levels of the following activities were considered:

1. Excavation, leveling, and PCC-related activities along with scaffolding, ladder, and erection of structural framework.
2. Centering and Shuttering work, including lifting, placing the mold in the correct position, hammering needles on molds to fix it to the right place.
3. Steelwork consists of cutting & bending of bars and tying stirrups to rebars.
4. Concreting included making the transfer of materials, concrete mixture, pouring of concrete.
5. Masonry work viz. transfer & mixing of materials, plaster, curing, watering.
6. Drivers of tractor, loader and crane operators were interviewed.
7. Carpentry work involved wood cutting and related activities.
8. Wiremen wall cutting for wiring work, sealing the gaps, and earthing.

QEC tool developed by David et al. [15] was adopted for the interviews of the workers. The questionaries (Fig. 1) and the scorecard are shown below (Fig. 2) [15].

Exposure scores Worker's name:_____ Date:_____

Observer's Assessment

Back

A When performing the task, is the back *(select worse case situation)*

A1 Almost neutral?
A2 Moderately flexed or twisted or side bent?
A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. **Does the back remain in a static position most of the time?**

B1 No
B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). **Is the movement of the back**

B3 Infrequent (around 3 times per minute or less)?
B4 Frequent (around 8 times per minute)?
B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands *(select worse case situation)*

C1 At or below waist height?
C2 At about chest height?
C3 At or above shoulder height?

D Is the shoulder/arm movement

D1 Infrequent (some intermittent movement)?
D2 Frequent (regular movement with some pauses)?
D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with *(select worse case situation)*

E1 An almost straight wrist?
E2 A deviated or bent wrist?

F Are similar motion patterns repeated

F1 10 times per minute or less?
F2 11 to 20 times per minute?
F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

G1 No
G2 Yes, occasionally
G3 Yes, continuously

* *Additional details for L, P and Q if appropriate*

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

H1 Light (5 kg or less)
H2 Moderate (6 to 10 kg)
H3 Heavy (11 to 20kg)
H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

J1 Less than 2 hours
J2 2 to 4 hours
J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

K1 Low (e.g. less than 1 kg)
K2 Medium (e.g. 1 to 4 kg)
K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

L1 Low (almost no need to view fine details)?
*L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

M1 Less than one hour per day or Never?
M2 Between 1 and 4 hours per day?
M3 More than 4 hours per day?

N At work do you use vibrating tools for

N1 Less than one hour per day or Never?
N2 Between 1 and 4 hours per day?
N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

P1 Never
P2 Sometimes
*P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

Q1 Not at all stressful?
Q2 Mildly stressful?
*Q3 Moderately stressful?
*Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* L _____
* P _____
* Q _____

Fig. 1 QEC questionnaire [15]

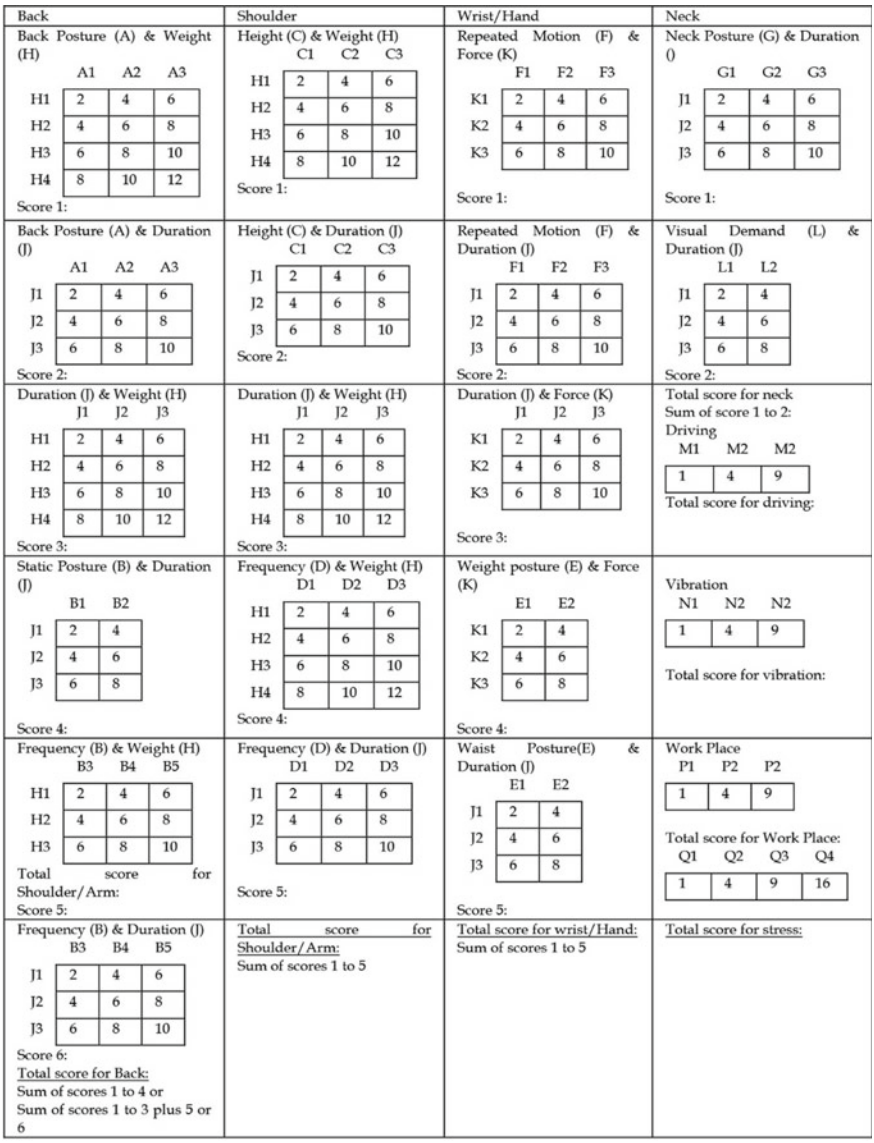

Fig. 2 QEC scorecard [15]

QEC scorecard was used to assess MSDs in four main body parts of workers viz. back, shoulder, wrist/hand, and neck. Based on the calculated scores of various activities, the risk levels were decided.

The study was carried out on 75 construction workers, and the risk exposure level was calculated using the QEC tool. Table 1 shows the details of surveys and activities.

Table 1 Details of surveys

Occupation	No. of workers	Jobs involved
Labor (excavation)	8	Excavation, dressing, PCC, levelling
Labor (scaffolding work)	4	Scaffolding, support laying
Labor (centering and shuttering)	11	Centering, shuttering
Labor (steelwork)	17	Stirrups tying, bar bending, bar cutting
Labor (concreting)	5	Concrete mixing, pouring of concrete in structural members
Mason	10	Mixing of mortar elements, plasterwork
Labor (watering)	3	Curing and watering
Labor (driver)	10	Tractor driver, crane operator, loader driver
Carpenter	4	Furniture work
Wireman	3	Electrician
Total surveys	75	

Site visits were conducted, and photographs of workers' postures were taken, which were later assessed. The postural analysis is described in the following section.

4.2 Postural Analysis of Workers

Postural analysis of workers was done to assess the validity of the QEC tool (Figs. 3, 4, 5, 6). Activities described in Sect. 4.1 were considered for the study.

While tying the stirrups, the worker needs to twist his wrist frequently and has to stand and sit while tying for top & bottom reinforcements of a beam respectively (Fig. 3a, b and c). It was observed that shuttering work involved maximum twisting

Fig. 3 Worker tying stirrups (back slightly twisted while standing and excessively twisted, knees bent, shoulder stretched while sitting)

Fig. 4 Worker doing shuttering work (back excessively twisted, knees bent)

Fig. 5 Worker doing plasterwork (back moderately twisted, knees bent)

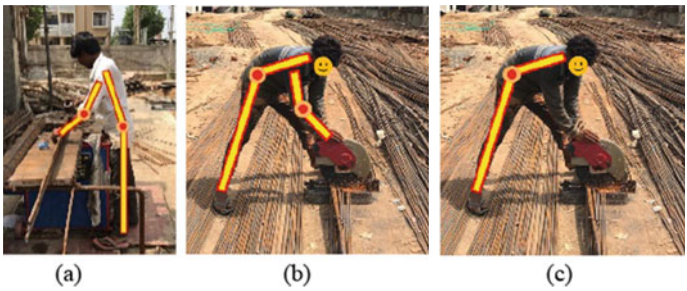

Fig. 6 Worker bending the bar (back almost straight while standing, wrist and shoulder bent & back moderately twisted, neck stretched)

of the back as it required mostly a sitting posture (Fig. 4a, b). It involved twisting of the wrist as well as knees. Mason, who was doing plaster had an excessive twisting of the back as he had to take mortar by bending his back and put it on the platform to do plasterwork. He had the continuous movement of the hand above as well below his waist (Figs. 5a, b). The worker involved in bar bending had excessive wrist movement; his back and shoulder were not much twisted (Fig. 6a). The worker involved in reinforcement cutting had back being moderately twisted and had a continuous movement of the shoulder and wrist. Neck was stretched as shown in Fig. 6b, c.

5 Results and Discussions

Analysis of collected data and its implications is discussed in the following section. Since QEC tool has concise score card and covers most of the activities causing MSDs, it is adopted in this study. Using this method, interviewing workers becomes most viable, since a score-card is already available. Linking of QEC results with fish bone diagram helps to identify root causes of MSDs.

5.1 Interpretation of the QEC Scores

The exposure scores for various body parts have been categorized into four exposure categories: Low, Moderate, High, or Very High. The scores of various body parts were calculated. Table 2 shows QEC standard exposure level body part-wise and element-wise [15].

Table 3 shows the QEC scores of various activities for various body parts. Table 4 shows most affected body parts and exposure level due to various activities.

From Table 4, it was observed that majorly affected body part while performing most of the activities was shoulder (53.33%), followed by back (37.33%), and wrist/hand (10.67%). The risk exposure levels for other criteria such as driving, vibration, work-pace, and stress was found to be low to moderate. However, steel workers were found to have maximum QEC score related to back. Since they require more physical effort, the psychological impact was also high for them, and so is the stress level. Concreting work was having highest score for vibration as well as work pace due to restricted durations of concrete pouring (within 30 min after preparing the wet mix). Driving and vibration tools related activities have a low level of risk.

Table 2 QEC standard exposure level body part wise and element wise [15]

Score	Low	Moderate	High	Very high
QEC standard exposure level body part wise				
Back (static)	8–15	16–22	23–29	29–40
Back (moving)	10–20	21–30	31–40	41–56
Shoulder/arm	10–20	21–30	31–40	41–56
Wrist/hand	10–20	21–30	31–40	41–56
Neck	4–6	8–10	12–14	16–18
QEC standard exposure level element-wise				
Driving	1	4	9	–
Vibration	1	4	9	–
Work pace	1	4	9	–
Stress	1	4	9	16

Table 3 Average QEC scores of various activities for various body parts

No.	Activity	Back	Shoulder	Wrist/hand	Neck	Driving	Vibration	Stress	Work pace
1	Steel work	44.8	42.0	38.7	16.0	1.0	3.6	8.1	4.8
2	Centering and shuttering	46.4	52.5	36.7	17.3	1.0	2.9	4.1	3.2
3	Mason	37.2	39.8	33.6	14.2	1.0	1.6	4.1	3.3
4	Drivers	22.4	34.0	32.8	15.8	8.0	1.6	4.8	3.6
5	Excavation	41.0	45.7	31.7	13.7	1.0	3.5	6.8	4.8
6	Concreting	18.8	45.2	37.2	12.4	1.0	4.8	6.0	6.4
7	Carpenter	27.0	37.0	38.5	10.5	1.0	3.3	5.3	2.5
8	Scaffolding and support laying	30.5	42.5	37.3	12.3	1.0	2.1	3.1	1.8
9	Curing and watering	20.0	26.0	22.0	10.0	1.0	1.0	1.0	1.0
10	Wireman	28.0	35.3	29.3	13.3	1.0	3.0	8.0	4.0
11	Cleaning	40.0	32.0	40.0	12.0	1.0	1.0	1.0	1.0
12	Levelling	20.0	30.0	22.0	14.0	1.0	1.0	1.0	1.0

Table 4 Most affected body parts and exposure level

Activity	Most affected body part	Exposure level
Steel work	Back (44.8)	Very high
Centering and shuttering	Shoulder (52.5)	Very high
Mason	Shoulder (39.8)	High
Drivers	Shoulder (34.0)	High
Excavation	Shoulder (45.7)	Very high
Concreting	Shoulder (45.2)	Very high
Carpenter	Wrist/hand (38.5)	High
Scaffolding and support laying	Shoulder (42.5)	Very high
Curing and watering	Shoulder (26.0)	Moderate
Wireman	Shoulder (35.3)	High
Cleaning	Back and wrist/hand (40.0)	High
Levelling	Shoulder (30.0)	Moderate

The overall stress in workers was of moderate level and work pace is impacted moderately.

5.2 Fishbone Diagram

Based on the above discussion, a fishbone diagram was prepared to find the root causes in order to study factors causing MSDs in workers (Fig. 7). The five factors causing MSDs are (1) method, (2) manpower, (3) material, (4) equipment, and (5) environment, and various aspects of the same were analyzed. The fishbone diagram helps to know the root cause behind the MSDs found in workers. The factors are discussed below:

Method. Manual Material Handling is the most prevalent method in small construction sites. Activities, such as, concrete mixing, bricklaying, plastering, etc., are done manually leading to rigorous physical work which increases the chances of MSDs in workers [16].

Material. Materials at small sites are handled manually. For example, cement bags weighing 50 kg are lifted by workers on their backs. Such heavy weights with continuous bad postures lead to MSDs in workers. Mobile platform trolleys can be made available on-site to address such issues.

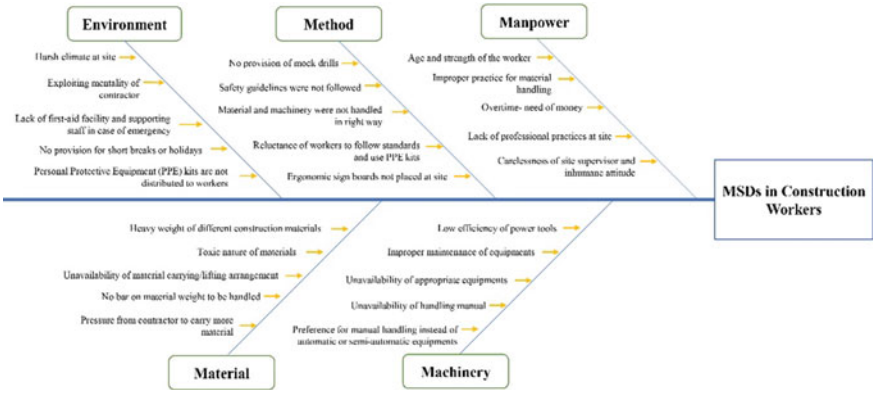

Fig. 7 Fishbone diagram to identify root causes of MSDs in workers

Manpower. Indian workers are not much literate, and most of them are semi-skilled. They lack in implementing tasks most efficiently. Improper body postures while performing task leads to MSDs [17]. Firms can arrange workshops to train workers to perform their job more scientifically, which would optimize their physical effort.

Equipment. Workers using equipment and machines like vibratory tools for compaction, cutting tools for reinforcement, etc., would create long-term damage to their hearing ability. While hammering (e.g., In shuttering work), it imparts jerks to the worker's body. Continuous exposure to such unwanted jerks can cause MSDs.

Environment. The site environment is quite harsh for the worker, especially exploited by the local contractors. Local sites do not have proper safety equipment, viz. helmets and PPE kits for laborers, making them vulnerable to hazards. Masons work on an uneven surface, which is a slipper, causing the risk of slip of leg. Generally, workers are adapted to hot climates, but studies have shown that continuous work in hot climatic conditions has significantly reduced their productivity. During the night shift, many workers feel issues of fatigue of the eyes [7].

6 Conclusion

The present research attempted to study the MSDs found in Indian construction workers. A total of 75 construction workers were interviewed in three different cities of India, based on research questionaries tool known as QEC. Activities related to excavation, steelwork, shuttering and centering, masonry work, scaffolding, concreting, and material transfer (using loader, tractor) were considered for the study. The QEC tool, activities and body parts impacted due to the same were identified, which significantly caused MSDs. Shoulder and back were recorded as majorly affected due to MSDs. The activity, 'Centering and Shuttering' has the highest

exposure level affecting the shoulder, followed by the back. A fishbone diagram is prepared to find the root causes behind MSDs in workers. Better quality standards at the workplace and a reduction in manual material handling can improve workers' work performance, thereby reducing MSDs in them. The decrease in MSDs can improve productivity on-site, thereby reducing the chances of accidents on site. To reduce the impact of MSDs on workers, solutions could be by providing elevated platforms available for easy operations in granite cutting and brickwork activities, use of a ladder to improve posture. To avoid unnecessary upper limb movement, workers should work from a reasonable height. Also, an attempt made in this study about root cause analysis related to MSDs can help in reducing impact of MSDs. The method employed in present study is based on in-situ visual observations. Hence, some observations like body postures and movement of body parts of the worker on the site would be interpreted differently compared to another person. Some standardized methods of the survey would address the above issue, which needs to be explored.

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Discomfort Experienced by Students While Attending Online Classes During the Pandemic Period

Edison Gundabattini, Darius Gnanaraj Solomon, and Preethi Sheba Hepsiba Darius

Abstract Online teaching and learning method is widely adopted to provide a safe working environment to both teachers and students during the pandemic period. While this method is helpful to carry out the process of teaching and learning successfully, a few challenges lead to discomfort for both teachers and students. A survey was conducted to know the advantages and disadvantages of the online teaching and learning process. About 457 students have taken part in this survey. The responses given by them have been analyzed and the results are presented. There are many advantages in this system as follows: teachers and students need not travel to colleges and they can work from home, students need not walk a long distance in Universities following the choice based credit system, the PowerPoint presentation is available to every student at a distance for students to view them comfortably, the lecture is heard by every student at the required volume, students can learn at their own pace, teachers and students can enjoy the home environment as well as the care extended by family members while carryout the teaching–learning process virtually. But there are many challenges experienced by students while attending online classes which are as follows: They are distracted by a noisy environment, poor internet connectivity, clarity in teaching materials, feeble audio system, and traveling distance. Guidelines are given to students on how to cope up with the online teaching–learning process using the principles of Ergonomics.

Keywords Online teaching-learning · Discomfort · Noise · Internet connectivity

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1 Introduction

Pandemic due to Covid-19 has brought a tremendous implication on the learning. A lot of research around the globe has been conducted through surveys with close-ended questionnaires and open-ended questionnaires to assess that. A strong and stable internet connection and the accessibility of electronic learning gadgets such as tablets, laptops, computers, and smartphones are indispensable for online learning. Equally important is having a designated learning area that is free of distractions from the domestic front and freely accessible social media. However, not all students are fortunate enough to have these facilities at home. There are many other factors discussed in this paper that indicate both the positive and the negative responses. Most of the urban students are happy as they could save time in traveling and they are accessible to the internet. But most of the rural students were not so happy as they have to face frequent power cuts and network issues. Studies and researches have been done all over, indicate a similar kind of impact on student online learning. E-learning tools brought excitement and awareness to new technology among the student community, while this mode of learning is also a kind of great concern as the students learn in an isolated environment without any social connection.

Fatima et al. [1] had analyzed the discomfort felt by the students and the faculty members through the survey. The survey was to investigate the online assessment efficacy. There were many challenges to the students depending upon their geographic location. Students from rural areas faced the challenges of poor network connectivity and electricity/power failure. In general, the challenges and discomfort were due to laptops slowing down, equipment overheating, computers/laptops not compatible with software's, bandwidth issues when using images and video, background noise if all microphones are kept unmute, loss of connectivity, and the necessity to reload/reboot repeatedly. This was further complicated by laptops 'freezing' when all the students signed on at the same time. Fewella et al. [2] had investigated the academic performance of the students making use of online e-learning tools for their technical feasibility. Most of the students were enthusiastic to learn through these tools as these tools were user-friendly and available free in the open-source. Students and faculty members found the e-learning approach was more convenient as they could access academic content anytime and anywhere an infinite number of times. This could allow for a much more flexible, step-by-step follow-up of the course, and they could also upload files, videos, and online links. But a considerable number of students wanted a detailed audio explanation for the video exercise recordings. A significant number of students found it difficult to see videos in dark colors as their eyes were stressed to look into them again and again, instead they preferred only light colors for better visibility.

Ahmadon et al. [3] had given a thorough assessment on online learning mode in the University setup. Few students were happy to get help privately from their teacher through the instant messaging apps (Whatsapp, Telegram, etc.). The investigation also indicated that inability to focus, unstable internet connectivity, and feelings of unfairness in the assessment were the cause of concern for many students. Some

of the students had to struggle hard to acquaint themselves well with the different types of operating systems, configurations, computer software, etc., as they found the complexity of the technology was too much for them. Investigations also revealed that some of the students were not motivated enough by the members of the family as every one of them is having their challenges related to their work due to this sudden development of pandemic.

Nijakowski et al. [4] had studied to assess the effectiveness of modern e-learning in dentistry with endodontics for the fourth-year students during the COVID-19 pandemic. Students found e-learning tools are interesting to enhance their learning capability and to the individualized pace of learning with fun. But some students stated that they were not happy to learn in isolation with decreased concentration and without the social contacts disabling them from the interpersonal dynamic learning. Jiang et al. [5] had investigated the approval rate of the undergraduate dental students with online dental teaching practices in contrast to the standardized resident physician training students during the COVID-19 pandemic at Zhejiang University in China. The study indicated that the dental students found that online learning significantly encouraged their pursuit of knowledge in dental education. But the real challenge was the inadequate real-time eye contact and facial communication, which was uncomfortable in the online learning approach. Jia et al. [6] had investigated the impact of the e-learning approach on students' learning experiences and their abilities. Studies revealed that the e-learning tools enhanced the student learning interest levels and improve their comprehensive ability. E-learning tools were found to be having a great influence on students' autonomous learning. But students found it uncomfortable with meagre learning resources and inadequate design classroom activities.

Singal et al. [7] had listed the challenges being faced by the medical and dental students during their remote anatomy learning. Most of the students felt that online learning was user-friendly and gadgets such as smartphones, laptops/desktops, and tablets are handy in the learning environment. Some of the students agreed that learning by video-recorded classes, followed by a power-point presentation was fruitful. The majority of the students found difficulty in time management, lack of self-motivation, and were distracted by home comforts or discomforts. Also, they were distracted by some online games, notifications, messages, and social media. Most of them accepted that they missed their real campus environment, companions, cultural and sporting events. A significant number of students felt that the lack of proper gadgets, high bandwidth, and strong internet connections are barriers to their current learning process. They felt that they are missing face-to-face lectures, discussions with their classmates, and interaction with mentors to grasp and learn. Some rural students with restricted or poor internet access, internet network was a potential barrier for their effective online learning. Findings indicate that the students with the same environment and circumstances in the campuses have equality to learning.

Qadir et al. [8] aim of this study was to identify the usefulness of e-learning on students' learning performance; to determine whether the students considered the tool to be useful and easy for learning. Students indicated that they were comfortable in uploading and downloading the learning materials and also in the flexible autonomous learning. A significant number of students indicated that they were uncomfortable

with the distracting environment which was accessible online. Gherhes et al. [9] had surveyed the preferences of learning during the pandemic, Covid-19. Most of them indicated that the e-learning system enabled them to learn with the time efficacy, the convenience of working from home, as well as the accessibility of various documents online. Nevertheless, a considerable number of students were dissatisfied due to the lack of student/teacher interactions, lack of interaction with peers, and socialization. They had also indicated that they felt discomfort with the technical problems encountered during the Internet connection and were critical about their lack of practical applications.

Mohammed Khan et al. [10] had examined the school students' perceptions and challenges regarding e-learning during the COVID-19 pandemic through their study. Investigations indicated that students were happy that their traveling time and cost were saved. Students were excited with the awareness of technological literacy due to online classes. Nevertheless, they were deeply disappointed with the inadequate interaction with teachers in online classes. Most of the students expressed that their motivation levels were low to study in online classes due to a lot of distractions in the home. The majority of them were felt discomfort in doing their projects in isolation without proper communication. Their discomfort was also due to the restriction in outdoor activities, eye strain problems, headache, and social media distraction while attending the online classes. Aiyanyo et al. [11] had investigated the effects of the pandemic on the foreign students living in South Korea. Most of them were positive as they could access course materials, access classes, and were creative through the online classes. However, the majority of the foreign students were mentally worried about their future as they were not able to understand better through the online classes. Most studies focus on a particular course [1, 4, 5, 7] or only in one University [3, 9]. The demographic for the survey is a mixture of engineering and medical students pursuing degrees in the southern part of India.

The studies above highlight both the positive and negative impacts of online learning. The consensus is that even though there is a significant amount of discomfort associated with online learning due to psychological, socio-economic, and technological factors, it is inevitable due to the pandemic. The novelty of this work is that based on the analysis of the survey and inferences made, user-centered design (UCD) recommendations based on ergonomic principles are proposed for all the major stakeholders in online learning. The principles of ergonomics in the context of online learning are: Students should have a comfortable & congenial environment, efficient tool (laptop/mobile phone) connected to high-speed high-quality broadband internet wi-fi, good audio/video systems, and minimum walking/travel for attending classes.

2 Methodology

A survey form was designed and the survey was conducted among 457 students studying in Universities, Engineering colleges, and Medical colleges. The questionnaire was designed to answer the following research questions. The questionnaire was designed using radio buttons where respondents may choose the statement most applicable to them and checkboxes where the respondents may choose multiple statements applicable to them.

The ergonomics issues considered in the research are:

- Comfortable work environment.
- Comfortable work area.
- Efficient tools and equipment.
- Noise.

The experience of online learning was gauged by the response to the following 3 questions.

- Are you distracted by TV and other activities at home?
- Are you learning at your own pace comfortably during online learning?
- Do you learn better with uninterrupted network connectivity?

The effectiveness of online learning based on ergonomic principles governing visibility, sound, and accessibility was assessed based on the response to the following questions.

- Are you able to hear the lectures clearly?
- Are you able to see the PPTs used by your teacher clearly?
- Are you able to reach online classes without walking/traveling long distances?

The feedback given by the students is segregated according to University, Engineering College, and Medical College and analyzed. The discomforts experienced by each category of students are presented. Guidelines are given based on the principles of Ergonomics for alleviating their discomfort so that everyone will have a better workplace for improving the quality of online learning during this pandemic period. The feedback collected from students on the questions mentioned above was analyzed and the results are presented through Figs. 1, 2, 3, 4, 5, 6 and 7 in the following section. Results from the ANOVA test and post hoc tests are examined to determine the significance of the results of various groups of institutions.

3 Results and Discussions

A survey on online teaching and learning was conducted. Students pursuing engineering and medical programs took the survey. As shown in Fig. 1 students pursuing their engineering degrees in VIT University, CMR Institute of Technology, Medical

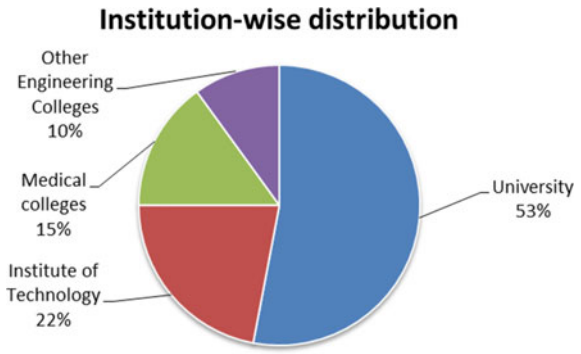

Fig. 1 Distribution of students institution-wise

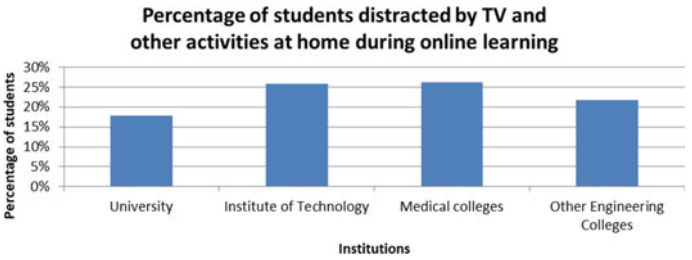

Fig. 2 Percentage of students from different institutions distracted by TV

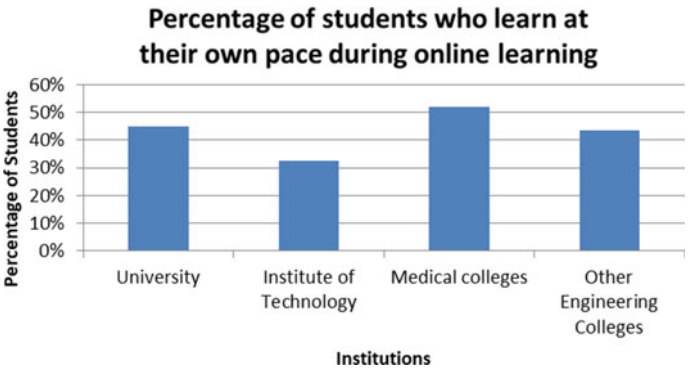

Fig. 3 Percentage of students who learn at their own pace comfortably during online learning

colleges, and other Engineering colleges took part in this survey. Table 1 shows the number of respondents from each Institution.

Figure 2 shows the percentage of students in each Institution who are distracted by TV and other activities at home during online learning. More percentage of medical college students are distracted by these activities compared to students attached to other Institutions. Environment noise levels, such as those from the TV or people

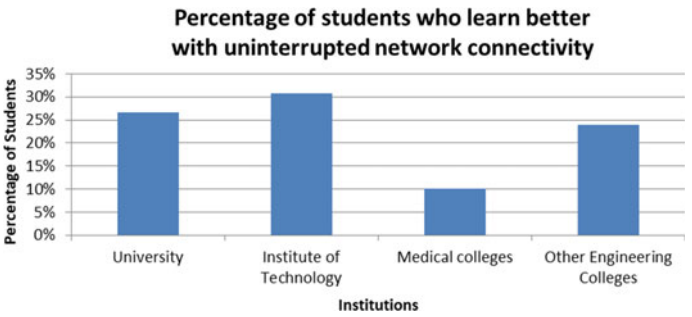

Fig. 4 Percentage of students who learn better with uninterrupted network connectivity

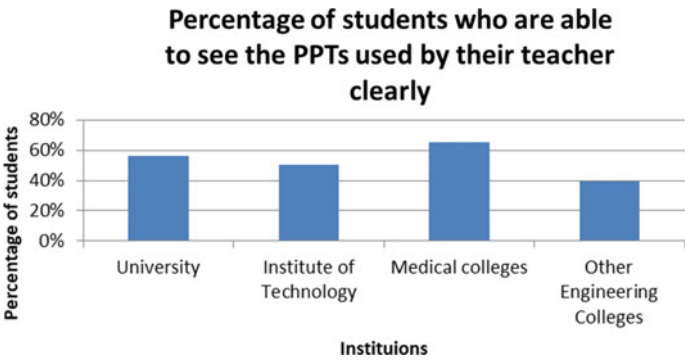

Fig. 5 Percentage of students who can see the PPTs clearly during the online learning

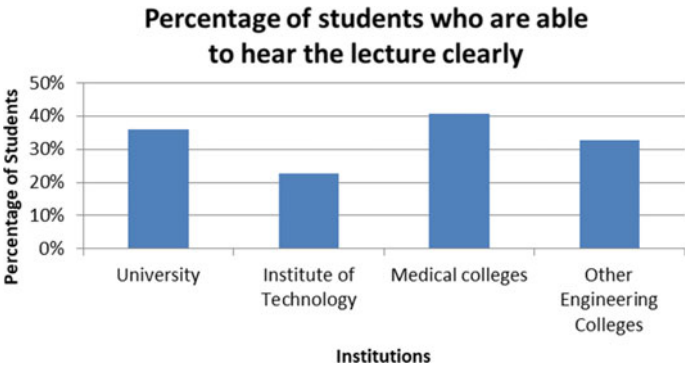

Fig. 6 Percentage of students who can hear the lecture clearly during online learning

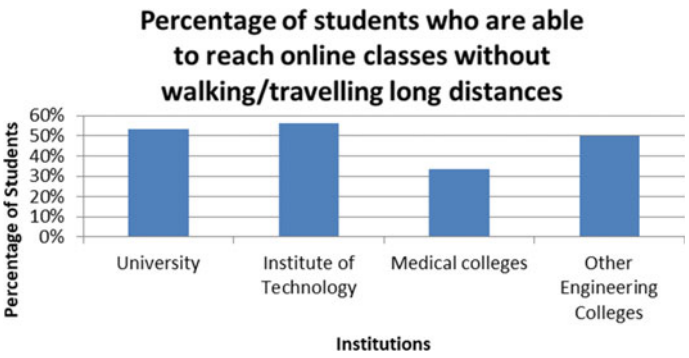

Fig. 7 Percentage of students who can reach online classes without walking/traveling long distances

Table 1 Institution-wise responses

Institutions	Total respondents
University	241
Institute of technology	101
Medical colleges	69
Other engineering colleges	46

talking have been shown to affect study home environments in research. The response from our brain to stimuli learned in a low noise environment can be carry forwarded to a high noise environment but not vice versa [12].

Ergonomically designed study rooms are to be provided to children for excelling through online learning. Activities distracting online learning are to be reduced to provide a congenial environment for learning. This may be financially burdensome for the family but during this pandemic, the costs for travel, leisure, entertainment that otherwise parents allocate for college-going teenagers is drastically reduced. Gaurav and Sheik report that the average education level of parents of engineers and doctors in India is 12 years which is 4 years more than that of the average worker [13]. Based on the NSSO unit-level data, the premium, i.e., the difference in earning of the next level of education has been on the rise over the last two decades [14]. If the assumption is that parents of children of students pursuing engineering and medicine are financially capable, then a separate room would improve the quality of learning during this pandemic. If the parents cannot afford to build another room, then they are expected to provide a congenial environment in the available space by sacrificing their normal routine by not watching TV, not making loud conversations, not entertaining guests and visitors during the pandemic period to help children to have effective online learning.

From ANOVA and post hoc tests, it was found that F value is 1.9363 and $F_{critical}$ is 3.0178; $\alpha = 0.05$ and $p = 0.1456$ indicate that there is no difference between groups.

The responses from students on 'distracted by TV and other activities in the home' is the same across all the groups.

Figure 3 shows the percentage of students who learn at their own pace during online learning. It is seen that 52% of medical college students learn at their own pace. The faculty members teaching the subject are expected to upload ppts, videos, and learning resources in an online platform from where all students can download and learn at their own pace. Studies report that the course design is crucial for the effectiveness of self-learning [15, 16]. Based on the survey results it may be inferred that the faculty of medicine provides a good course design that aids the students to learn at their own pace as compared to other institutions. From the result of the ANOVA and post hoc test, it is seen that F(3.46) is greater than $F_{critical}$(3.02); it is evident that the variance between groups is significant.

Figure 4 shows the percentage of students who learn better if they have uninterrupted network connectivity. It appears that students of Medicine are the least affected by network connectivity whereas the student in Institutes of technology is the most affected. This is further checked by the ANOVA test; F(5.203) is greater than $F_{critical}$(3.0178) and hence the disparity among groups is significant. President Abdul Kalam wanted even remote places in India must be connected by the internet irrespective of whether it is close to a city or far away from the city. The government has to provide internet at all places and parents should be willing to spend more money to provide better connectivity to students so that they can learn better through online platforms.

More percentage of students can see the PPTs used by their teachers clearly during online lectures as shown in Fig. 5. In some Institutions, the size of the classrooms is large and the screen provided for the projection is small. When students attend lectures physically, the projected information may not be clear to all students. Students sitting in front of the screen may be comfortable whereas other students who sit on the left extreme or right extreme may not have a comfortable view and may develop neck pain or headache. If the font size used by the teacher is small, reading becomes difficult for the students who sit far away from the screen. All these problems are eliminated in online learning. Every student is seated in front of the screen and the magnification of the screen can be adjusted. F value is found to be 1.81 and $F_{critical}$ is 3.01which indicates that there is no difference between the groups.

The percentage of students who can hear the lectures clearly in online mode is shown in Fig. 6. In physical classrooms, only the students who sit in the first few rows hear the lecture clearly, if the voice of the faculty is feeble. But in online learning, the faculty is given a mic and students use speakers. It depends on how the mic is arranged by the faculty and the speakers used by the students. If everything is properly arranged all students must be able to hear the lectures clearly through online mode. But less than 40% of the students only hear the lectures clearly and other students are not able to hear clearly. Statistical analysis revealed that F value is 4.21 and $F_{critical}$ is 3.01which indicates that there is difference between the groups. A lot of effort is required from all stakeholders to improve the quality of audio so that online learning is more successful.

A fully flexible credit system (FFCS) is followed in universities. As a result, students have to move from one class to another class located in different buildings. 10 min break is given between subsequent classes but sometimes it takes more than 10 min to walk from one end to another end of the University. In colleges, where FFCS is not followed, students find it difficult to travel amidst traffic jams and to reach their first-hour class on time. All these problems are solved through online classes in which walking/traveling is totally eliminated. As seen from Fig. 7, University students, as well as students of the Institute of Technology, responded more to this question. The statistical analysis reveals that F value is 6.19 and $F_{critical}$ is 3.01, which indicates that there is difference between the groups.

Most of the studies cited from the literature were based on a particular course. The study highlights the best practices online or what is currently being followed amidst the COVID-19 pandemic. This study focuses on the plight of engineering and medical students in the southern part of India. Based on the outcome of the survey, UCD recommendations are provided for all major stakeholders in higher learning.

4 Suggestions for Improving Online Learning Based on the Principles of Ergonomics

The principles of ergonomics give solutions to discomforts faced by users for developing "UCD". The model followed by the Republic of Korea who is leading the online technology wave in Asia was examined closely [11, 17, 18]. Also, the best practices reported from universities in several countries were studied [3, 9, 10]. Even though India is lagging on the ICT infrastructure, several significant strides have been made in the last decade that made the Internet accessible to a higher percentage of households with over 700 million internet subscribers in India as of 2020 [13]. A tremendous effort is currently in place to ensure broadband access to all villages by 2022 [14].

The following suggestions are given to reduce discomfort experienced by students while attending online classes during the pandemic period:

1. Ergonomically designed study rooms are to be provided to children for excelling in online learning
2. Activities distracting online learning are to be reduced to provide a congenial environment for learning.
3. Uninterrupted network connectivity, uninterrupted power supply, high-speed broadband internet wi-fi are to be provided to improve online learning by students.
4. PPTs are to be made with better clarity; mic and speakers are required to be adjusted properly to facilitate a better online teaching–learning.
5. Postures occupied by faculty members as well as students are required to follow the principles of ergonomics to overcome occupational health hazards while performing online teaching and learning.

5 Summary

The discomfort experienced by students while attending online classes during the pandemic period is found by surveying 457 students studying various Institutions like universities, the Institute of Technology, Medical colleges, and Engineering colleges. The feedback received from students is analyzed and the results are presented. It is shown that a lot of students are suffering from internet connectivity problems, Lectures are not audible and PPTs are not clear. Many students are struggling with the present home environments that are not giving conducive environment to them for having online learning without any distraction. Suggestions are given for solving problems using the principles of ergonomics for improving the quality of online learning.

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Measuring the Work Stress Level Among Nurses During Second Wave of Covid-19 in India

Shilpi Bora and Pallvi Rani

Abstract The purposed of the study to measure the work stress level of Nurses and their mental health outcomes due to second wave of Covid 19. An electronic survey was emailed to nurses who are working with the covid patient in in different parts of India from 2020 to 2021. A total of 40 responses were included in this study. Perceived Stress Scale (PSS) method was used to measure the perception of stress level and it is found that Nurses are suffering from (almost 83%) moderate stress level and 10% of them have high stress. Majority of the respondents were concerned with the stress related issues in their workplace due to this pandemic. Hence, the Nurses should discuss about the stress level they are experiencing, workplace adaptation during this covid, proper training and mental support.

Keywords Covid 19 · Nurses · Stress level · Mental health

1 Introduction

In January 2020, the World Health Organization (WHO) announced an international public health emergency due to an outbreak of a novel coronavirus disease, COVID-19 [1]. In December 2019, patients with unrevealed pneumonia were discovered in Wuhan, China [1, 2]. The WHO declared this disease a public health emergency, accompanied by the declaration of pandemic status in March 2020 [3]. As the world faces an ongoing global health emergency, the top priority is pandemic containment [4–6]. The COVID19 outbreak, in particular, has posed a significant threat to public health [6, 7]. COVID-19 has infected over 87,000 health staff in India, accounting for about 74% of the case burden and 86% of COVID-19 deaths [8]. The death toll for disease outbreaks is very disturbing and surprising to both the general population and mainstream health professionals [6, 9]. The rapid spread of disease, as well as

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the increasing number of positive tested cases and deaths, has created a lot of fear and anxiety among the public. The current coronavirus (COVID-19) epidemic has had a significant impact on the mental health of both healthcare and non-healthcare professionals. Providing security and fostering overall well-being both during and after an outbreak is becoming increasingly important in overcoming these effects on an individual's mental state.

Nurses have traditionally played an important role in infection prevention, isolation, containment, and public health [10]. Unlike doctors, nurses work around the clock to promote community health literacy, disease prevention, detection, and diagnosis, as well as to promote rapid healing, life support treatment, and end-of-life care. They face major psychological consequences as a result of extremely long working hours, a hard workload, a lack of personal protective equipment (PPE), over-reporting by audio-visual and social media, as well as many news outlets, and a high risk of infection among handling employees [3, 11]. Anxiety is also linked to the development of depression in the long term as a result of the epidemic's burnout [12]. More than half of those polled had symptoms of depression and anxiety, and nearly a third had symptoms of post-traumatic stress disorder [10], according to a recent study of nurses' perspectives on functioning during the early stages of the pandemic in the United States.

Nurses' reactions to the current pandemic's stress must be seen through the perspective of occupational health and safety. In 2019, the WHO classified burnout as an occupational disorder rather than a medical condition, despite evidence that both occupational and personality factors contribute to burnout [13]. Stress and burnout have been identified as workplace hazards for nurses all over the world [14]. Health workers, particularly nurses, are on the front lines of the COVID-19 epidemic response, according to the WHO. Pathogen exposure, long working hours, psychological distress [15], exhaustion, occupational burnout, stigma, and physical and psychological abuse, to name a few things [16], make them vulnerable. The International Council of Nurses (ICN) and the WHO began considering nurses' mental health issues because it is critical to continuing to provide the best possible treatment [17, 18]. Controlling infectious diseases necessitates maintaining nursing staff's mental health [18, 19].

The majority of research on COVID2019's disease situation has centred on epidemiological investigation, prevention and control, diagnosis, and care at this time. Fewer studies looked at the mental health of clinical medical staff during the COVID19 outbreak [1]. The responses to an open-ended question about stressful situations in the survey could reveal the circumstances and conditions that influenced nurses' reactions to working during the pandemic. In order to guide successful workplace and national responses in the future, previous qualitative research on pandemics has emphasised the importance of understanding frontline nurse perspectives [17, 20]. A better understanding of current trends could benefit organisational and workplace efforts to reduce the tension and ill-health that nurses are dealing with during and after the pandemic [10].

2 Methodology

A cross-sectional analysis was conducted. Snowball sampling technique was used to conduct an online survey of nurses across the country. A total of 40 nurses who work with Covid patients in India (states like Assam, Delhi, Bihar, Jharkhand) between the year 2020 and 2021 were emailed an electronic survey that included other social media. The Perceived Stress Scale (PSS) among nurses was investigated using a questionnaire that was divided into two parts during second wave (of Covid 19). The first segment included questions about age, marital status, educational status, experience (in years), type of hospital, and involvement in the treatment of corona-affected or suspected patients, hospital grade, weekly rest time, and number of night shifts in the previous month, professional attitude, and recently completed infection-prevention training. Questions related to your mental health, such as unexpected situation, inability to control the important things in life, feeling nervous and stressed, feeling confident in your ability to deal with problems, feeling like things were running their course, couldn't cope to everything, the things that could control irritations in life, that took over, were angry about things, felt difficulties and could not overcome them, all were taken into account with the PSS scale. The percentage statistic was used to compare stress levels with PSS.

2.1 Perceived Stress Scale (PSS)

PSS is an effective tool for determining stress levels. PSS-14, PSS-10, and PSS-4 are the three different versions of PSS. Professor Cohen created the first PSS, which consisted of 14 items in two dimensions [21]. Shorter versions of the items were chosen from the original PSS-14. The PSS scale has been used to assess tension in patients, cops, teachers, nurses, pregnant women, and the elderly in numerous nations [22, 23]. PSS-14 was originally exposed to the Chinese public by Professor Yang et al. in 2003 [24].

The data was collected using a standardised questionnaire adopted from the WHO and verified for perceived stress. A 10-item scale called the PSS-10 was used to collect data on perceived stress. A 5-point Likert scale is used in the tool. Each item was graded using the following scale: 0 = Never, 1 = Almost Never, 2 = Sometimes, 3 = Fairly Often, and 4 = Very Often. The overall score was based on a scale of 0–40.

3 Result and Discussion

The data was collected between April 18th and May 18th, 2021. Owing to time constraints, there were a total of 40 respondents were selected.

Table 1 Demographic variables of the nurses

Variables	Variable category	%
Gender	Male	12.5%
	Female	87.5%
	Others	0%
Marital status	Married	55%
	Unmarried	45%
Educational qualification	H.Sc	10%
	B.Sc	74%
	M.Sc	16
Family type	Nuclear	62.5%
	Joint	32.5%
	Single parent	5%
	Others	0%
Occupation	Medical student	30%
	Healthcare profession	70%
Working experience	0–5 years	12.5%
	5–10 years	85%
	More than 10 years	2.5%
Types of hospitals	General medical and surgical hospital	65%
	Super specialty/multi-speciality hospital	5%
	Medical college and hospital	22.5%
	Clinics	0%
	Others	7.5%
Involvement in treatment of corona affected patients	Never	2.5%
	Often	37.5%
	Very often	60%
Weekly rest time	0 h	7.5%
	Less than 48 h	62.5%
	More than 48 h	30%
Number of night shifts	0 nights	12.5%
	Less than 10 nights	85%
	More than 10 nights	2.5%
Participation in infection-prevention training	Attended	65%
	Not attended	35%
Fear of infecting family members	Yes	87%
	No	13%

Of the total participants (n = 40), 87.5% were women (and 12.5% men), and almost more than half of the 32 respondents (74%) had a B.Sc. Nursing as an educational title. 55% of the nurses were married; with 85% they had experience between 0 and 5 years; where 62.5% came from the family nucleus. 70% of nurses work in the health sector, while 30% of current B.Sc. Students helping their seniors during this time of pandemic. A total of 65% of respondents working in hospitals were found to be from private hospitals (Table 1).

Table 1 also indications that the nurse's involvement in treatment of corona affected patients 60%, where they get weekly rest time up to 63–65% of the participants involved in infection-prevention training whereas 35% not attended any training. Almost 85% of the nurses were stress-free, meaning they worked less than 10 nights a week as a shift worker (at night). Nearly 87% of nurses are concerned about infecting their family members, while only 13% are not concerned because they live in a hostel or PG (paying guest). Table 1 shows that nurses experience mental health issues on a variety of levels, both professionally and individually [16]. Nurses, like other healthcare professionals, are at risk of contracting COVID 19 when in close contact with infected patients [25] has a significant impact on their mental health. They also stated that a shortage of medical staff, lack of medical supplies, protective equipment, nurses working long hours, a lack of practical aspects, and witnessing the death of Covid 19 patients on a regular basis all affect stress levels and mental wellbeing [6, 21]. About every nurse has experienced problems such as contracting an infection and becoming a disease carrier [26]. Furthermore, they are concerned about transmission to their own families and loved ones, especially children and the elderly [4]. Nurses, despite being the main caregivers, experience emotional distress for a variety of reasons [27].

As the second wave of Covid-19 causes Indians to rush for hospital beds, oxygen, drugs, and even cremation slots, public hospitals are struggling to recruit physicians, nurses, and other medical staff (Aarefa, 2021). However, due to the high nature of the employment, the majority of the available roles are only temporary fixes: short-term contracts with few rewards or safety nets. According to healthcare personnel, the scale of the COVID second wave, combined with a paucity of resources, has had a substantial impact [28].

The second wave of COVID19 poses a significant threat to public health, especially for the Indian population. COVID19 is a complex, contagious, and generally vulnerable epidemic. This second wave poses significant problems for prevention and social control, as well as for first-line treatment, and caregivers who have supported this treatment are under great stress.

During this pandemic, anxiety and stress are the most common mental health problems among nurses [29]. Nurses are under a lot of stress, anxiety, depression, and burnout, all of which are impacting their health [3, 6, 8, 30]. According to a survey, 41.3% of the 1131 respondents in the First Wave of Covid 19 had depression, with severity ranging from mild 134 (11.8%), moderate 155 (13.7%), serious 61 (5.4), and extremely severe 117 (10.3%) [6]. However, in this study, the Covid 19, which is considered to be the Second Wave from March 2021 onwards, is found to

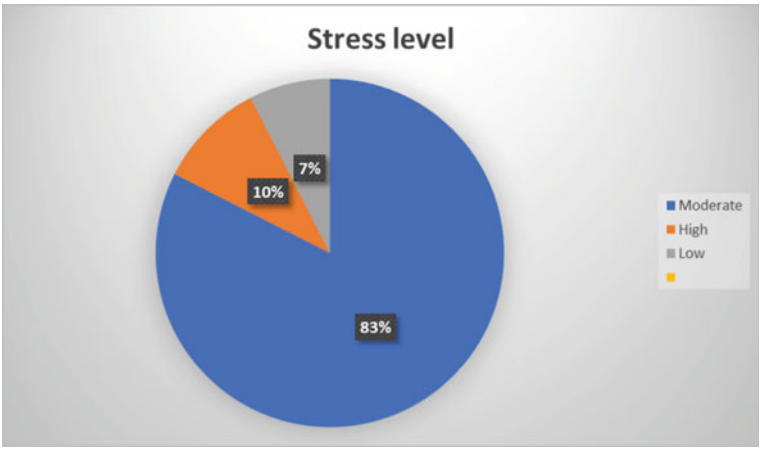

Fig. 1 Level of stress perceived by the participants N = 40

be different in terms of stress levels, with moderate (83%) being the most common, followed by high (10%) and low (8%) (Fig. 1).

Table 2 specified that the majority of respondents were irritated by things that happened outside on a regular basis, while others felt well on a regular basis. On the other hand, the majority of respondents were able to properly complete crucial events in their lives, while others were unable to cope with all that was going on around them.

Subsequently, they felt alone and psychologically lonely while they worked in a closed work setting, according to popular statements. Nurses were concerned about a possible shortage of PPE. Furthermore, widespread use of PPE resulted in bodily pain or injuries. After donning their PPE, nurses wore it for the duration of their shift in the COVID-19 unit. Nurses couldn't drink or go to the bathroom, and some even had hearing and vision problems at the end of an 8-h shift that was later reduced to a 6-h shift due to the nurses' difficulties. Other worries and fears for these nurses included their own safety and the welfare of their families. They felt bad for not being able to be with their loved ones during the pandemic. When nurses were placed in an unfamiliar geographic area and work setting, they also encountered culture shock.

Nurses working in intensive care units and respiratory departments were at high risk of infection, and they were worried about contracting the virus and transmitting it to their families, friends, and colleagues [18, 31, 32]. Medical instruments and procedures add to the stress, making it more difficult to perform medical tasks [33].

Table 2 shows that the majority of respondents (60%) are occasionally irritated as a result of something unexpected that occurred in the previous month. Similarly, 60% of respondents said they have experienced obstacles that have piled up so high that they have been unable to overcome them. 40% of those polled believed they were never on top of things. Table 2 shows that 55% of the respondents were apprehensive and stressed at times. However, 55% of nurses are capable of controlling irritations in your life. This are the few results from where it can be understood that they have

Table 2 Perceived stress scale (PSS) among the nurses

Questions	Total respondent	Never (%)	Almost never (%)	Sometimes (%)	Fairly often (%)	Very often (%)	Total (%)
Q1 How many times in the last month have you been upset because something unexpected happened?	40	10	0	60	12.5	17.5	100
Q2 How often in the last month did you feel like you couldn't control the important things in your life?	40	12.5	2.5	45	25	15	100
Q3 How often have you felt nervous and "stressed" in the last month?	40	7.5	5	55	17.5	15	100
Q4 How often in the last month have you felt confident in your ability to handle your personal issues?	40	7.5	10	52.5	17.5	12.5	100
Q5 How many times in the last month did you feel things were going your way?	40	22.5	22.5	40	12.5	2.5	100
Q6 How often in the last month did you find that you couldn't keep up with everything you had to do?	40	12.5	10	50	22.5	5	100

(continued)

Table 2 (continued)

Questions	Total respondent	Never (%)	Almost never (%)	Sometimes (%)	Fairly often (%)	Very often (%)	Total (%)
Q7 How many times in the last month have you been able to control annoyances in your life?	40	10	7.5	55	20	7.5	100
Q8 How many times in the last month did you feel on top of things?	40	40	10	32.5	15	2.5	100
Q9 How many times in the last month have you been enraged by circumstances beyond your control?	40	5	10	42.5	25	17.5	100
Q10 How many times in the last month did you feel as if your problems were piling up so high that you couldn't handle them?	40	12.5	7.5	60	12.5	7.5	100

Q1, Q2, Q3, Q6, Q9 and Q10 carry scales: 0–4
Never = 0, Almost never = 1, Sometimes = 2, Fairly often = 3, Very often = 4
Q4, Q5, Q7 and Q8 carry scales: 4–0
Never = 4, Almost never = 3, Sometimes = 2, Fairly often = 1, Very often = 0
After summing all the scales, it is found that 33 respondents have moderate stress, 4 respondents has high and 3 respondent has low stress.
Ranking: 0–13 Low Stress.
14–26 Moderate Stress.
27–40 High Stress.

less stress than that of first wave coronavirus. As shown in Fig. 1, 83% of nurses are under moderate stress, 10% are under high stress, and 7% are under no stress. This could be because they're used to it and know how to treat corona virus infections in humans.

4 Conclusion

The rapid onset and high infectivity of COVID-19 make clinical prevention and outbreak management difficult. According to our findings, the COVID-19 outbreak in India has put nurses under a lot of stress. Self-defense training, ensuring enough nurses for emergency and fever clinics, reducing the number of night shifts and ensuring adequate rest, timely updates of the most up-to-date information to keep nurses informed, and encouraging nurses to share clinic information are all examples of effective measures that should be taken. In addition, nurses with children should be given more attention and support from their families.

As part of an ongoing procedure, all medical organisations should perform a stress audit to determine the severity of stress and analyse it in order to create an action plan. To reduce perceived stress and improve mental health among nurses, new strategies and organisational support should be built. To begin, governments must systematically identify groups at risk of displaying severe symptoms of perceived stress, such as nurses, and provide early intervention. Spreading awareness and informing non-psychiatric care teams about mental health evaluations will help ensure prompt diagnosis. Finally, it is critical to raise awareness among nurses about the importance of addressing their mental wellbeing with early and appropriate support steps, such as normalising feelings, communicating clearly, meeting basic needs, allowing sample work breaks, and offering psychotherapy.

Nurses, in particular, should be given special attention because they are at a high risk of experiencing psychological disorders. As a result, it is strongly suggested that systematic screening for psychological disorders and early intervention be implemented.

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Evaluation of Comprehensibility of a Sign by Triangulation Method

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Abstract Comprehensibility is the most crucial factor for the design and evaluation of a sign. Evaluation of sign's comprehensibility through appropriate method is of utmost necessity before its implementation to avoid the wrong interpretation and thereby devastating impact. Hence, a comprehensibility evaluation of a sign was attempted using the triangulation method to overcome intrinsic biases from a single method study. One important COVID-19 warning sign was shown to 50 volunteers (43 male 7 females, graduates, and non-OSH experts) who were employees of India's leading manufacturing organization. Two different methods were used for the comprehensibility assessment of the given sign. One was in the form of a score, and the other was in the form of a short descriptive answer. Two OHS experts evaluated both types of responses. The threshold was tuned between 30 and 100%, and comprehensibility results were recorded accordingly. The given sign was found comprehensible to 40% of the volunteers in Method-1 and 48% in Method-2 when comprehensibility was judged based on the gold standard, i.e., 60% (score = 0.6). The findings of both methods were found to be almost similar and effective in evaluating comprehensibility. The triangulation using two different methods produced consistent findings and revealed high positive correlation of data between two methods (Pearson r = 0.86). Both collected data and methods were thus validated and qualified for the generalization of the observed result. Hence, researchers became confident about the results of the sign's comprehensibility, although the sign was found less comprehensible, needing further research and redesign.

Keywords Semiotic · Sign · OSH · Sign design · Design research · Cognition

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1 Introduction

Signs, specifically warning signs, are long being used in an attempt to improve the health and safety of the workplace in an environment where other methods of controlling hazard(s) are infeasible [1]. The intent of the sign is to convey the desired message unambiguously, which doesn't seem to work all the time [2]. This leads to unwanted accidents and/or, health issues which becomes detrimental for employees in an organization(s). The study of comprehensibility or understandability of a sign is

Table 1 Literature showing various studies and methods related to the evaluation of signs

Author (year)	No. of subjects	Technique/method	Outcome
Burt et al. [8]	21	Four symbols of correct lifting posture were shown, open-ended questions, later coded using various lifting criteria	The study helped identify correct lifting postures and showed a significant increase in the adoption of correct lifting posture when the symbol was present in comparison to a controlled condition
Brantley and Wogalter [9]	20	Thirty-one symbols were shown to collect open-ended written responses, written with and without probe questioning, oral response with probe, and without probe question. Two raters scored the response	Results showed that the test methods that included follow-up questioning elicited more information from participants and increased comprehension rates in oral and written test formats. The results have implications for cost-effective symbol design and evaluation
ISO-9186-1 [4]	50	Manual/computerized display of graphical elements/text in a given context, answer(s) in words (open-ended response), two response categorizers, five standard categories, combined results of all countries	This method is an existing, recognized, and standard method for assessing the comprehensibility of signs

(continued)

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Table 1 (continued)

Author (year)	No. of subjects	Technique/method	Outcome
Reis et al. [2]	12	A virtual environment prototype was used to study the subject's hazard perception, simulator sickness, sense of presence, and level of engagement was assessed by observation, post-hoc questionnaires, and semi-structured interviews	As workers grow older, their ability to comply with such signs is adversely affected by age-related deficits. Safety signs are not always effective in communicating the intended message or necessary information to the employees
Kaufmann and Ramirez-Andreotta [10]	11	They used participatory design, formative evaluation, open-ended discussion, three examiners to evaluate the factsheet	Graphic elements outweigh text; concepts per figure should be minimal to ensure comprehension. The need for formative evaluation, information design prototyping, cultural model of risk communication is demonstrated
Arcia et al. [5]	10	Case1: Two asthma control infographics-ISO 9186 open-ended responses written down by interviewer where the participants could change their response. Interviews were audio-recorded and later transcribed. Two raters scored responses, and a third person acted as a tie-breaker	Modified ISO-9186 method, Subjects responded very favourably to the infographics, and most of them expressed intentions to take self-management actions such as better medication adherence, smoking cessation, etc.
	40	Case2: Heart failure symptoms monitoring-ISO 9186 for verbal administration, non-leading probing questions, two questions like ISO 9186 with 5 points likert scale	63% successfully comprehended text plus red-yellow green gradient line, or text plus line graph. 38% comprehended text plus pressure gauge icons or text only

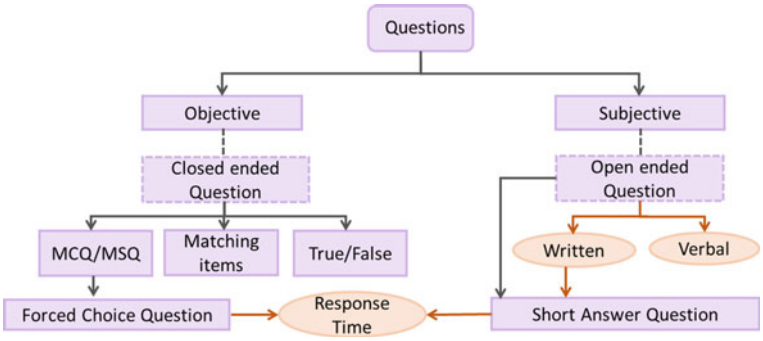

Fig. 1 Various patterns of questions for comprehension test of sign(s)

crucial considering the aforesaid issues where misinterpretation of any sign/symbol may result in disaster or acute health hazard. Comprehensibility/understandability is a predominant factor than any other factors like legibility, learnability, etc. [3]. The intention of the sign is to communicate the message of the hazard clearly. This could be ensured through a standard evaluation method that confirms the comprehensibility of the existing and designed sign(s). According to ISO 9186-1, comprehension test is defined as the procedure to quantify the degree of understanding of a proposed graphical symbol. Literature narrates various methods of sign evaluation (Table 1) following and deviating from ISO-9186 standards [4]–[5] using various patterns of questions [6]–[7] as shown in Fig. 1.

However, there is a paucity of literature narrating the triangulation of methods for the comprehensibility evaluation of Occupational Health and Safety (OHS) sign(s). Triangulation method uses multiple data sources or multiple methods to establish a comprehensive understanding of a phenomenon [11, 12]. The advantage is that one method may compensate for the weakness of another method [13]. Besides, the mixed-mode research of triangulation method helps in generalization [14]. Motivated from the literature, a study was conducted using triangulation method to minimize the procedural biasedness in data collection and/or interpretation that might come from a single method.

2 Methodology

The objective of the study is to evaluate the comprehensibility of a sign using method of triangulation so that the comprehensibility results truly reflect the opinion of the target audience. Fifty participants who were not OHS experts participated voluntarily in the study [4]. The participants were selected based on purposive sampling with mean age of 33.01 and standard deviation of 5.9. They did not have any color bindness or eye defect (self reported). The participants were asked to view a 5 min video showing the experimental protocol with an example of a trial with signs of

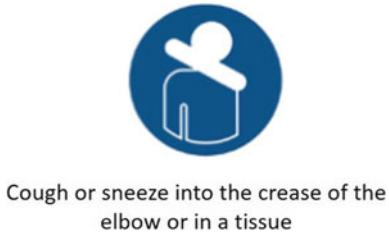

Fig. 2 Diagram of COVID related warning sign

different context, which in no way matched with the original sign. A (COVID-related) warning sign was chosen for the actual study (Fig. 2). The sign is intended to convey "Cough or sneeze into the crease of the elbow or in a tissue". This sign is meant to prevent spreading of serious respiratory diseases like COVID-19, influenza, etc. Two methods were used for data collection. The subjects were asked demographic questions, with the main study-related questions. In the first method (Method1), the subjects were asked to assign a score about their understanding of the sign. The score ranged between 0.0 and 1.0, with an interval of 0.1. 0.0 signifies "not comprehensible, 0.5 as partially comprehensible, and 1.0 as fully comprehensible. In the second method (Method2), subjects were asked to write a short descriptive response or answer about the message the sign conveyed. Two OHS experts evaluated the responses and assigned a score (0.0. or 0.1 or ……1.0) for each response based on pre-agreed terms. The experts were trained and experienced in conducting behavioral experiments with human subjects and analyzing their responses [15]. Descriptive statistics were collected for both the data, and data were checked for its distribution. The inter-item reliability [16] and the interrater consistency were checked. The mean of the scores (in Method2) was considered in this study.

For bivariate analysis of the two methods, three correlation method results for Pearson's, Kendall's tau, and Spearman's rho were considered. The data distribution deviated from a true normal distribution; however, parametric test like Pearson were also considered here besides the non-parametric tests because Pearson's correlation coefficient was recently proved to offer a substantial improvement in statistical power even for distributions with moderate skewness or excess kurtosis [17]. To calculate the percentage of volunteers or subjects who comprehended the message, 60% threshold was considered the gold standard by the experts. The other feasible threshold results were also calculated for understanding the phenomena. The two methods were compared using correlation study. The overall evaluation process is shown in Fig. 3.

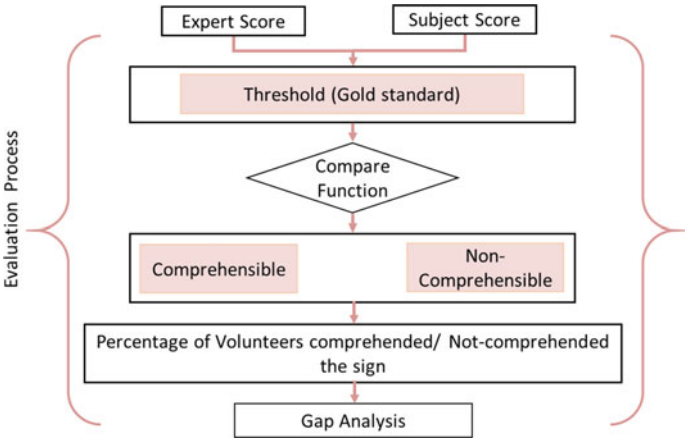

Fig. 3 Triangulation model for evaluation of comprehensibility

3 Results and Discussion

Descriptive statistics (Table 2) shows that skewness Z value is within the range of ±1.96 for both the data, i.e., subject/volunteers' rating (Method1) and the expert score (Method2). The kurtosis Z value for them is not within the range of ±1.96, which shows that the data is kurtotic (platykurtic). The Kolmogorov Smirnov test and the Shapiro–Wilk test (Table 3) show that the p-value (sig.) is less than 0.05. This result conforms to the kurtosis result that data seems to deviate from the normal distribution.

The distribution, however, does not affect the study here as it reflects only the dispersed score, which is the opinion of subjects. Subjects' opinions can vary and

Table 2 Descriptives for method1 and method2

Methods	Skewness			Kurtosis		
	Statistic	Std. error	Z value	Statistic	Std. error	Z value
Method1	0.26	0.33	0.79	−1.43	0.66	−2.16
Method2	0.00	0.33	0.01	−1.64	0.66	−2.48

Table 3 Test for data distribution

Methods	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Method1	0.23	50	0.00	0.83	50	0.00
Method2	0.16	50	0.00	0.88	50	0.00

[a] Lilliefors significance correction

depend on their decision about a score. Though the subjects were exposed to the scoring process before the actual experimentation, they showed significantly less understanding and experience about scoring. An intelligent guess of experts made from the study narrated that subjects rated his or her understanding as 0.1, or 0.2 or 0.3 or 0.4 or even 0.5 for the sign with very less understanding. This is confirmed by the subjects' scores. Similarly, they rated themselves as 0.7, or 0.8, or 0.9, or 1.0 with a complete understanding of the sign. This fact was confirmed after the detailed analysis of the subjects' scores. These deviations could have been avoided by simulation of the study; however, the same could not be made possible due to lack of facility. Even experts might sometimes get biased while scoring the responses though their scores are based on pre-agreed terms. Hence, the mean score of the two experts was collected as the representative score [18].

The inter-item reliability is found to be encouraging ($r = 0.86$) and hence confirms the internal consistency [19]. The inter-rater consistency is high (Table 4) for the Method2, considering the scores were assigned based on pre-agreed terms.

The intraclass correlation, the intraclass correlation coefficient for the lower bound and upper bound at 95% confidence interval for the average measure, is above nine (>9), which is excellent (Table 5). The result claims that there is high inter-rater reliability between the raters. Bivariate correlations gave a high correlation between the two methods. Pearson's Correlation coefficient is 0.86, Kendall's tau is 0.69, and Spearman's correlation is 0.84. The same test validates that there is a high positive correlation between the variables (score) of the two methods. This way, the bivariate correlation used in this study helps to validate data as well as the methods. Besides, this correlation study demonstrates a high external validity because the results reflect the relationship existing in the real world, and there is no manipulation or control by the experts. Again, the high positive correlation coefficient value between the two

Table 4 Inter-rater consistency

Cronbach's alpha	Cronbach's alpha based on standardized items	N of items
0.99	0.99	2

Table 5 Intraclass correlation coefficient

	Intraclass correlation[b]	95% confidence interval		F test with true value 0			
		Lower bound	Upper bound	Value	df1	df2	Sig
Single measures	0.98[a]	0.93	0.99	139.26	49	49	0.00
Average measures	0.99[c]	0.96	0.99	139.26	49	49	0.00

Two-way mixed-effects model where people effects are random and measures effects are fixed

[a]The estimator is the same, whether the interaction effect is present or not

[b]Type A intraclass correlation coefficients using an absolute agreement definition

[c]This estimate is computed assuming the interaction effect is absent because it is not estimable otherwise

variables demonstrates the strong correlation between them irrespective of their data distribution. Hence the study can be generalized beyond the studied people and the situations studied [20].

According to the ISO/ANSI standard, a symbol must reach a criterion of at least 67 or 85% correct (percentage of volunteers correctly understood the message) in a comprehension test to be considered as acceptable or can be used [21, 22]. In this study, the comprehensibility test considered the threshold as 60% (0.6) as the gold standard, decided by the factory experts considering the severity of the context. This means that the volunteers who scored equal to or more than 0.6 were considered as successful in comprehending the meaning of the sign. In another way, the sign which could cross the 60% threshold, were considered comprehensible. This method differs from the usual comprehension test. In the comprehension test followed by ISO/ANSI, the participants of the test are asked to write the meaning of the symbol according to their understanding. If they do not understand the symbol, they are asked to write "I don't know." Based on their response, the frequency is counted, and finally, a percentage of correctness in comprehension is calculated. In this study, the frequency of the volunteers who scored equal to or more than 60% was considered for both methods.

The message conveyed by the COVID sign is mandatory and must be understood by most people to stop spreading this deadly epidemic. The percentage (s) of volunteers/participants who understood the sign's meaning (frequency of correctness) was computed based on the threshold. The threshold was tuned from a valid range, i.e., 30–100%, and results are shown in Table 6.

A Plot of the result shows a trend of participants' comprehension for both the methods (Fig. 4). At the 40% threshold, both the methods have a very nearer comprehensibility result for the sign with a difference of +2% (Method2–Method1). At the 80% threshold, there is a difference of −2% (Method2–Method1). Method2 is the gold standard and controlled by experts; hence deviation from this method is being studied. In Method1, the subjects were exposed to the marking procedure before the experiment. Despite being a novice in respect to the experts, their method gave a good result.

The graph of Method1 and method2 uncovers the possibility of the subjects' underconfidence about their knowledge or understanding of the sign. It has been analyzed that though they wrote the correct meaning of the warning sign, they assigned themselves with less scores. This might have happened because they are less experienced in scoring.

Table 6 Comprehensibility of sign by two methods

		Threshold (in percentage)							
		30	40	50	60	70	80	90	100
Method1	C	62	56	50	40	32	30	26	20
Method2	C	58	58	56	48	40	28	18	12

C comprehensibility expressed in percentage

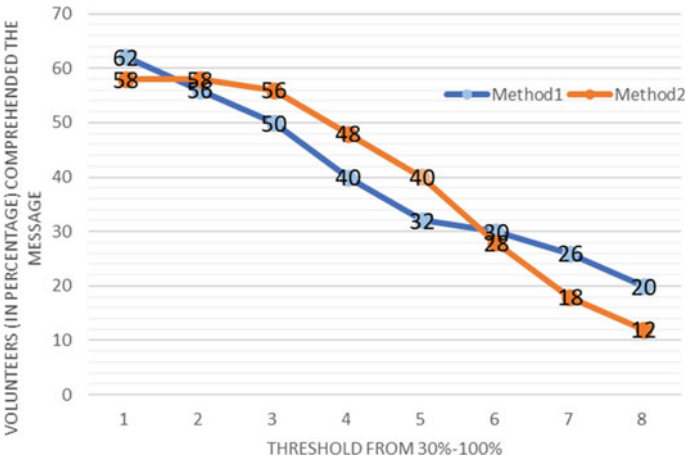

Fig. 4 A plot of the percentage of volunteers comprehension of the message against various threshold

Table 7 Result of various perceived difficulty level

Methods	Very difficult	Difficult	Nor easy nor difficult	Easy	Very easy
No. of subjects	16	8	11	7	8

Every method comes with its strength and weaknesses, and there is no alternate for these methods under study. Both the methods have their shortcomings, and in triangulation method, one method counterbalances the other method. Based on the context and the factory scenario, the experts decided to have 60% cutoff or threshold for success in a comprehension test. It is seen that 40% of subjects (volunteers) were successful, and 60% were unsuccessful in the comprehension test in method1. Similarly, 48% of subjects were successful, and 52% were unsuccessful in method2. The results examined in the study demonstrate that the comprehensibility level or understanding level for the sign's message did not reach 70% of the volunteers. Again, if ISO/ANSI standards are considered, considering the valid range of threshold, i.e., 30–100% (Table 6), none of the percentages of volunteers' comprehension reached ISO or ANSI standard. Hence, from that viewpoint, the sign under study is considered for further research.

Despite the fact that the sign consists of both pictogram as well as text, the comprehensibility result is not up to the mark. The sign considered for study is standard, however present study shows that majority of the audience fails to comprehend the sign correctly. This resulted in further research of the sign. A redesign and further study has been proposed (which is out of the scope of this paper). A further analysis uncovers the perceived difficulty level of their understanding and the mismatch between the pictogram and the text used to convey the message. Table 7 shows the number of subjects rated for various difficulty levels based on their understanding of

Table 8 Result of mismatch/match of the pictogram with its textual information

Methods	Strongly mismatch	Mismatch	Not sure	Match	Strongly match
No. of subjects	6	7	17	14	6

the sign. 48% of participants or subjects found the sign 'difficult,' or 'very difficult' together, and 22% found it hard to decide whether the sign is easy or difficult to comprehend. Another 30% perceived it as 'easy' or 'very easy.' Another result is shown in Table 8, in which the number of subjects' views are displayed based on their understanding of the mismatch/match between a pictogram and its text. It is found that 26% of the subjects' claimed a 'mismatch' or 'strong mismatch' between pictogram and text, and 40% claimed a 'match' or 'strong match' between them. 34% were not sure about their decision about match or mismatch between the picture and the text. An intelligent guess to justify the incomprehensibility of the sign might be (1) the target audiences are less exposed to such type of sign (2) only 26% of them claimed to have seen the sign previously (3) pictogram of the sign is abstract (4) ergonomic design principles may not be strictly followed during the design of sign (5) the context of use was provided however, the real scenario may not be perceived by the target audience etc. Hence, considering the investigated data and after a thorough study, it is decided that the sign needs to be redesigned and requires further investigation.

4 Conclusion

This research aims to evaluate and study the comprehensibility of a COVID-related sign. The Triangulation approach helped to generalize the result, which has always been an issue that is successfully dealt here. This mixed-mode approach is strong enough to deal with the biases and weaknesses of a single method of study. Two methods were used for the study, and there is a strong positive correlation between them which supports the data validity, method validity, and the external validity of the result. The mixed-mode study helped generalize the result, although the survey was conducted in a single manufacturing company located in different parts of India. The inter-rater consistency is found to be high, and the expert's opinion was considered as the gold standard for studying the weakness or strength of the other method. Descriptive statistics show that the data is slight kurtotic, but that does not affect the study. The sign under investigation is found to be less comprehensible. The difference between comprehensibility results for both the methods is found to be less, which shows the reliability (internal consistency) of the items. At 60% (0.6) threshold, the percentage of volunteers who comprehended the sign is found to be 40% in the case of method1 and 48% in the case of method2. This mixed mode of study is generalizable and replicable.

Further analysis on the subjects' rating for various difficulty levels based on their understanding of the sign reveals that 48% of participants or subjects found the sign 'difficult,' or 'very difficult,' and 22% found it hard to decide whether the sign is easy or difficult to comprehend. Another 30% perceived it as 'easy' or 'very easy.' Further analysis on the number of subjects' views on their understanding of the mismatch/match between a pictogram and its text reveals that 26% of the subjects claimed a 'mismatch' or 'strong mismatch' between pictogram and text, and 40% claimed a 'match' or 'strong match' between them. 34% were unsure about their decision about match or mismatch between the picture and the text. Hence, from the study, it may be concluded that the sign is not up to the standard and found to be less comprehensible by non-OSH experts. Future work lies in applying ergonomic principles of display design for the sign under study. The study recommends that there is a need for analysis and re-evaluation of the studied sign after a redesign.

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