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N. K. Rana
Aqueel A. Shah
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Technology Enabled Ergonomic Design

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N. K. Rana is presently working as Director of Theem College of Engineering, Boisar, Mumbai. Prior to his present association he held several responsibilities in educational institutes and government research institutes. He possess vast experience of more than 35 years at various levels. Dr. Rana completed his Masters and PhD degrees in Biomedical Engineering from Indian Institute of Technology Bombay. Dr. Rana has published and presented more than 65 papers in conferences and journals, book chapters and conference proceedings at International/National level and visited several countries for Keynote and Invited talk presentation. He has completed 12 sponsored consultancy projects at different places for various requirements. He was invited to deliver technical lectures during several Short Term Training Programs organized by Govt. College of engineering and other institutes. He has received "best research paper awards" at international and national conferences and also is a recipient of best academician award. He has guided several scholars for the PhD degree, Master's theses and many Under Graduate project work. Dr. Rana has been reviewing research articles for various International journals and conferences on regular basis. He is member on several committees of Mumbai University and many other Universities. Dr. Rana is a Fellow of IETE, Life Member Indian Ergonomics Society, Life Member Biomedical Society of India, Member IEEE U.S.A., Member ISA U.S.A., Senior Member IACSIT and serving these bodies through various responsibilities.

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Chapter 1
A Preliminary Study on Female Runners and Their Body Composition

Ekta Kapri, Ekta Melkani, Manju Mehta, and D. K. Sharma

1 Introduction

A good sport demands physically active, skilled, and technical person, who has comprehension regarding training, health fitness, and certification for nutrition basics (Saravanapriya 2019). Practice of any sport activity and physical exercise enhances the individual's physical fitness (Van Gent et al. 2007). Regular physical exercises, such as running, throwing, and jumping, increase rate of physical development and boost the athletic performance. Apparently, the performance of athletes needs specific biological profile with exceptional biomotor ability (Gabbett et al. 2008; Thorland et al. 1988; Bompa & Buzzichelli 2018). Among all of these physical activities running is the best way to get fit. It is one of the most popular sports activity practiced by amateur and professional. Any sport needs passionate player be it man or woman. Involvement of women in sports at some stage in the arena has been elevated around the twentieth century (Saravanapriya 2019 and Women's sports). A study on female athletes by Mayoclinic suggested that normal running can make muscles strong, stimulates growth hormone, enhances performance, and enhance life expectancy (Saravanapriya 2019). Elite and world-class female athletes involved in elite, middle, long distance and ultra marathons have positive effects of exercise on health. Having different physique compared to non-athletic individuals and with varied anthropometric and body compositions (Javed et al. 2013; Molla 2017). Body fitness and physique both have a significant relation to physical performance both mechanically and metabolically (Gabbett and Georgiell 2007; Boileau and Lohman 1997). In athletics, physical performance and strength are significantly related to athlete's anthropometry, and therefore a set of anthropometric dimensions were being suggested for examining the body composition of runners, such as body mass, body

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height, body mass index, body fat, length of the upper leg, length of limbs, circumference of thigh, and total skin fold thickness of the lower limb that could provide a general anthropometric assessment of the athletes (Slaughter et al. 1982; Bale et al. 1986; Carter and Yuhasz 1984; Legaz and Eston 2005; Tanaka and Matsuura 1982; Sharwood et al. 2002). In the high-level competitions, anthropometric profiles indicate whether or not the athlete would be suitable for the competition (Koley et al. 2010). It is observed in the studies that frequent running make changes to body composition (helps to increase lean muscle and decrease subcutaneous fat) (Saravanapriya 2019). Somatotype of a running athlete can determine one's running ability and indicates the running type. Somatotype fall into three categories: ectomorph (lean body mass), mesomorph (muscular body), and endomorph (soft muscle tissue) which are pure body types and the best combinations of two or more body types (Braverman 2018). Body composition affects the energy needed for physical strength in various sports (Koley et al. 2010). Long distance runner women having ecto-mesomorph and meso-endomorph body types exhibit better performance (Bale et al. 1985, 1986). High level of running tanning (competitive training) decrease the sum skinfolds and athletes' running performance related to physiological, anthropometrical, and training variables that are dependent upon the gender, length, and duration of performance (Anderson 1996; Morgan et al. 1989; Legaz and Eston 2005). Under the light of the above points, the present study aimed to examine the type of runners and the association among anthropometric parameters of female runner. More research is required on female runners' physical fitness such as somatotype, aerobic capacity, cardiovascular capacity, and muscular capacity.

2 Method

The study had been conducted on the female runners in the campus of CCSHAU, Hisar, Haryana. The objective of the study was to examine the type of runners and investigate the association among anthropometric parameters of the female runners. The study is based on primary data. Twenty female students were selected on the basis of their involvement in the running activities. All selected students were practicing either recreational running or competitive running, but few of them were regular. An interview schedule was prepared for collecting the primary data. On the basis of the interview schedule, out of these 20 runners, only 5 competitive runners were purposively selected. Those runners were practicing their running daily (morning and evening), having good physical health, and also involved in athletic competitions frequently. Anthropometric data of the five female runners were collected for further study. Body mass, body height, and thicknesses of skinfolds were measured and collected data were calculated by using an anthropometric method.

Body height was determined to the nearest 1 cm using an anthropometric rod. Body mass index (kg/m^2) was calculated from body mass and body height. Skinfold thicknesses were measured at the seven sites: chest, mid-axillary, triceps, subscapular, abdominal, suprailiac, and front thigh. Skinfold data was obtained using a skinfold caliper (Harpenden) recorded to the nearest 0.2 mm. The measurements were made three times on the right side and the mean of the three measurements was used for the analyses.

Body mass index was calculated with

$$\text{Quetelet index} = \frac{\text{Mass (kg)}}{\text{Height}^2\,\text{(mt)}}$$

Lean body mass was calculated with:

$$\text{Fat weight} = \frac{\text{Body weight} \times \text{Fat\%}}{100} \quad \%\text{Fat} = \frac{4.95}{\text{D}} - 4.5 \times 100\ \text{(Siriequation)}$$

where

D = Body density. According to Jackson and Pollock formula of body density for female.

D = 1.097–(0.0004697 × Sum of SF) + 0.00000056 × Square of the sum of skin fold sites)–0.00012828 × Age (yr).

2.1 Statistical Analysis

Spearman's correlation coefficient (r_s) is a non-parametric test, which measures the strength and direction of the association between two ranked variables. Spearman's correlation determines the strength and direction of the monotonic relationship between your two variables. Spearman's rank correlation formulas were used to find how strong a relationship among the anthropometric variables. The formulas return a value between +1 and −1, where +1 indicates a perfect association of ranks, −1 indicates a perfect negative association of ranks, and a result of zero indicates the weaker association between the ranks. MS Excel 2007 was used for statistical analysis.

3 Results

1. Type of runners:

   Running is performed over longer distances, for endurance, and with primarily aerobic metabolism examples such as jogging, road racing, and marathon (Novacheck 1997). The study categorized runners as beginners, intermediate runners, and competitive runners. Beginners and intermediate runners were further categorized into the interval and slow-continuous runners; competitive runners categorized into a sprint (100, 200 & 400 mt), middle-distance (up to 3000 mt), and long-distance runners (at least 3 km.). The study revealed that

35% were beginners and they had started running from the last 2 to 6 months. Out of these beginners, 71.4% were interval runner and 28.6% were doing slow-continuous running. About 30% of students were intermediate runners and practicing running for the last year. Out of these intermediate runners, half were interval runners and another half were slow-continuous runners. Another 35% of students were competitive runners and practicing running from at least 2 years up to 6 years (some of these were runners from their school time). Twenty percent of them were sprint runners (100 and 200 mt.) and 15% were middle-distance runners (1500 mt), no one was found in the category of long-distance running.

2. Anthropometric profile competitive runners

   For the collection of anthropometric data, competitive runners were purposively selected. They were practicing their running regularly, participated in athletic competitions frequently, and also have good physical health. Anthropometric measurements are a series of systematized measures of the physical properties that quantitatively express the dimensions of the human body size and shape. It is an indirect method of assessing body composition and body composition is an important indicator for evaluating health (Roche et al. 1996; Mondal and Mridha 2015). Anthropometric measurements include body weight, height, skinfold measurement, circumferences, and various body diameters. The weight provides a simple measurement of body mass and skinfold measurement describes the regional fat deposition (adiposity). Therefore, weight combined with skinfold measurement and body diameters can determine the amount of fat-free mass and fat mass (Molla 2017).

3.1 General Profile

The study carried out in the university campus found that 55 percent of female runners were 21–25 years old followed by 16–20 years (35%) and 26–30 years (10%). Study further found that 60 percent female runners were having height in between 1.6 and 1.7 mt followed by 1.5 and 1.6 mt (35%) and 1.7 and 1.8 mt (5%). About the body weight 80% runners were having body weight in between 51 and 60 kgs and 20% were having 41 and 50 kgs.

3.2 Anthropometric Profile

Based on the first objective, out of 20 female runners, 5 competitive runners were purposively selected for the anthropometric study.

Table 1 shows anthropometric data of five female runners involved in competitive running. The mean, standard deviation for age, height, weight, BMI, and body composition are presented in Table 1. The age of the selected competitive runners in

Table 1 Competitive runner's anthropometric profile

Variables	Mean ± SD
Age (yr)	20 ± 1.58
Weight (kg)	49.6 ± 2.79
Height (mt.)	1.59 ± 0.05
BMI (kg/m^2)	19.55 ± 1.35
Triceps (mm)	11.02 ± 1.71
Subscapular (mm)	13.62 ± 5.11
Chest (mm)	19.62 ± 2.03
Mid-axillary (mm)	16.56 ± 3.38
Suprailiac (mm)	15.72 ± 4.82
Abdominal (mm)	16.26 ± 4.28
Thigh (mm)	20.18 ± 5.92
FAT%	15.12 ± 2.56
Fat wt (kg)	7.53 ± 1.55
LBW (kg)	42.06 ± 1.94

the study varies from 18 to 22 years (20 ± 1.58) with mean weight 49.6 ± 2.79 kg, considered as normal body weight (Nuttall 2015), and height was 1.59 ± 0.05 mt. As a report by World Health Organization 1995, BMI splits into four categories: underweight (BMI < 18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9), and obesity (BMI ≥ 30), and BMI in the present study on female runners falls into normal weight category (19.55 ± 1.35 kg/m^2). Data of seven skinfolds were used to calculate the available fat weight, fat%, and lean body mass. American Council on Exercise categorizes fat percentage into: essential fat (10–14%), athletes (14–21%), fitness (21–25%), average (25–32%), and obese (above 32%) (Muth 2009); in present study, the mean fat percentage of female runners was found to be 15.12 ± 2.56% and lean body weight was 42.06 ± 1.94 kg, and therefore female runners fall into athletes category.

1. Spearman's Rank Correlation

Spearman's rank correlation is non-parametric version of Pearson's correlation coefficient, which helps to assess the relationship between two variables.

Table 2 shows rank correlations among the anthropometric variables. According to Spearman's rank correlation, it was found that age has a positive rank association with weight, height, BMI, and fat % ($r_s = 0.61$, $r_s = 0.91$, $r_s = 0.74$, and $r_s = 0$, respectively). The study shows a strong association between age and height of the female runners but there was no association between the age and fat percentage of the female runners. Chinedu et al. (2017) also found that there was strong correlation ($p < 0.001$) between age and the anthropometric parameters: weight ($r = 0.69$), height ($r = 0.31$), and BMI ($r = 0.61$). In the present study, the weight of the female runners has a strong association with BMI and fat weight ($r_s = 0.95$ and $r_s = 0.94$). BMI also

Table 2 Spearman's rank correlation among variables $n = 5$

Variables	Weight	Height	BMI	Fat %	Fat wt
Age	0.61	0.91	0.74	0	0.31
Weight	–	0.82	0.95	0.74	0.94
BMI	0.95	0.86	–	0.66	0.84

r_s = Spearman's rank correlation coefficient
BMI = Body mass index, wt = Weight

has a positive relationship with weight, height, fat%, and fat weight ($r_s = 0.95$, $r_s = 0.86$, $r_s = 0.66$, and $r_s = 0.84$, respectively). BMI and body weight have a strong association. The present study supported by Vuvor and Harrison (2017) found that body weight was correlated with body fat ($r = 0.67$).

4 Discussion

The study concludes that among all sports, running is the most popular recreational and competitive activity. The study includes beginners, intermediate, and competitive runners, and these runners practice running for different purposes, like for recreation, to improve their health, to improve their physical stamina, and to improve their performance timing. Beginners and intermediate runners were mainly interval runners and slow-continuous runners, whereas competitive runners range from sprint (100, 200, and 400 mt), middle-distance (up to 3000 mt), and long-distance runners (at least 3 km). Competitive runners were selected for anthropometric study because of their constant and regular involvement in running. The anthropometric profile of competitive runners was further selected to determine their body composition. All of these runners had been practicing for more than 2 years and took part in inter- and intra-university athletic meets. The study revealed that age, weight, and BMI were positively associated. Skinfold measurement to determine the presence of fat in different body parts helps to assess fat weight and fat% in the body. A runner having a low-fat percentage falls into the athletic category which indicates good health and leads to good race performance (Bale et al. 1986). An investigation by Ismail and Zawiak (1996) found that athletes with low body fat% can uptake maximum oxygen (VO_{2max}). The study further revealed that body weight and BMI have a perfect association among body weight, fat weight, and fat percentage. Ilman et al. (2015) concluded that the relation between BMI and body fat percentage was influenced by gender and age.

5 Conclusion

Present study concludes that the anthropometric variable helps to assess the body composition of the female runners. Anthropometric property has a marked effect on athlete's health and performance. This information will be helpful for the future study on long-distance runners and individual practicing other sports.

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Chapter 2
RETRACTED CHAPTER: A Survey on Early Prediction of Autism Spectrum Disorder Using Supervised Machine Learning Methods

K. N. Praveena and R. Mahalakshmi

1 Introduction

Nowadays, the world is facing lot of problems in medical field to diagnose the diseases in early stage. Doctors and specialists did not have the benefit of technology to identify a disease (Reeta et al. 2018) in prior in order to take precautionary measures to predict the diseases in early stage (Reeta et al. 2018). Once the situation is in extreme level and becomes too late for treatments, it couldn't help to diagnose the disease (Reeta et al. 2018). The epoch of "Big data" (Hyde et al. 2019) is set apart by both an essential increment in the sum at which information is produced and the assortment of information made (Hyde et al. 2019). The progress in volume, velocity, and variety of data is due in large part to the obtainability and affordability of various apparatuses and organization (Hyde et al. 2019) used to accumulate and analyze many different types of information (Hyde et al. 2019). Therefore, by using data science algorithms, the data can be analyzed efficiently to gain meaningful knowledge about the status of a person's health (Reeta et al. 2018). This increase in identifyting the technologies for the presentation of machine learning techniques in numerous grounds of learning.

Unique field is autism spectrum disorder (ASD) research. Autistic Spectrum Disorder (ASD) is a psychological disorder that hinders procurement of etymological, communication, cognitive, social skills, and stereotypical motor behaviors and capabilities. In the previous decades, ASD has been scrutinized by public and computational intelligence scientists exploiting innovative technologies like machine

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learning for early prediction and hence to reduce the diagnostic timing, with high precision and enhanced quality of diagnosis. Machine learning is a multidisciplinary research topic that employs intelligent techniques to determine beneficial secret patterns, which are exploited in prediction to improve decision-making. The techniques of machine learning like support vector machines, decision trees, logistic regressions, and others have been applied to datasets related to autism in order to hypothesis predictive models.

The principle kind of machine learning is sorted into two types, unsupervised and supervised learning (Hyde et al. 2019). This research paper is focusing on supervised learning. Supervised learning is a type of machine learning algorithm which uses a known dataset.

Supervised learning has two types of algorithms:

(1) Classification (for categorical data) and
(2) Regression (for continuous data).

A directed learning model is considered fruitful when the model can (a) precisely anticipate the objective outcome for a preparation dataset in a specific way of exactness and (b) be summed up to new datasets past those used to prepare the model (Hyde et al. 2019). To improve a model's capacity to make forecasts on future information, a strategy called cross-approval is regularly utilized (Hyde et al. 2019). This strategy permits a subset of the information to be taken out prior to preparing, so the model would then be able to be tried on new information (Hyde et al. 2019). A supervised machine learning model's is ordinarily estimated by precision (i.e., the capacity to accurately arrange into discrete classes) (Hyde et al. 2019). This might be estimated by thinking about affectability (i.e., the capacity of recognizing genuine positives) and explicitness (i.e., the capacity to distinguishing genuine negatives) (Hyde et al. 2019).

Autism Spectrum Disorder (ASD) Mental imbalance Disorder is a name for a scope of sicknesses having comparable conditions including Asperger Syndrome that influence an individual's social cooperation, correspondence, interests, and conduct. Throughout the long term, distinctive analytic labels have been utilized, for example, mental imbalance, autism spectrum disorder (ASD), autism spectrum condition (ASC), classic autism, Kanner autism, pervasive developmental disorder (PDD), high-functioning autism (HFA), Asperger's syndrome, and Pathological Demand Avoidance (PDA) (Park et al. 2016). In kids, the side effects of ASD are available before 3 years of age. Despite the fact that there is no remedy for ASD except for specific restorations can be utilized to improve the casualty's condition. The result of the analysis can help us in understanding the health condition, the skills, and education styles to be adopted for such people (Condy et al. 2019). It can also help us in taking precautions against certain practices which can worsen the victim's condition (Condy et al. 2019).

Manifestations of ASD can be analyzed in kids till year and a half old enough. In any case, ASD can't be perceived until the youngster goes to class. Because in school the child can interact with friends, and based on this one can predict the autism. If child's interaction is not proper and talks less, then it may lead to diagnosis.

Determination of disorder needs a great deal of amount of your time and worth. Prior recognition of disorder will be helpful for the patients with right treatment and medications in beginning period. It can avoid the patient's situation from declining advance and would like to diminish elongated tenure charge connected with hindered diagnosis. Along these lines a period efficient, exact, and simple screening test apparatus is especially required which would foresee mental imbalance attributes in an individual and distinguish whether they require complete chemical imbalance appraisal.

For analysis of ASD, there are diverse mechanical assemblies and approaches practiced by experts identified with expressive instruments. In the greater part of these examinations, the classification method is used.

Since there is a large variations in the symptoms and severities of ASD, diagnosis of ASD is the challenging task. It has been seen that machine learning calculations are broadly utilized and achieve great execution in different utilizations of autism spectrum disorder analysis.

This review adds to the comprehension of ASD research utilizing machine learning procedures. Presenting analysts to a review of these novel methodologies serves to heightening their comprehension of by what technique and where the field is developing.

The review paper is systematized as follows. Sect. 2 explains about autism spectrum disorder. Section 3 describes the related work. Section 4 tells about research in autism spectrum disorder using supervised machine learning algorithms. Lastly, Sect. 5 concludes the paper by emphasizing the investigation assistances and future thoughts to progress this work.

2 Autism Spectrum Disorder

Mental imbalance range issue is an assortment of multipart issues of the mind advancements such as remember trouble for social connections, dreary practices, and interchange. These issues root at youthful age of 2–3 years, and thusly indications of ASD might be acknowledged at a youthful age (Ibrahim 2019) Autism spectrum disorders are multiple times regular in young men than in young ladies (Condy et al. 2019).

2.1 The Causes of Autism

The causes of autism are as follows: (1) it can happen in children of any race, civilization, or communal family. (2) Chemical imbalance may occur because of specific blends of qualities which may build a youngster's danger in chemical imbalance. (3) A youngster with a more seasoned parent has a higher danger of chemical imbalance. (4) If a pregnant lady is presented to specific medications or synthetic substances, similar to liquor or against seizure meds, her youngster is bound to be medically introverted. (5) Other dangerous factors incorporate maternal metabolic conditions, for example, diabetes and stoutness. Examination has likewise going with mental imbalance to untreated phenylketonuria (additionally called PKU, a metabolic infection influenced by the nonappearance of a compound and rubella (German measles).

2.2 Autism Screening and Diagnosis

It is hard to get a definite conclusion of chemical imbalance. The specialist will accentuate on exercises and development of youngsters. Diagnosis of autism can takes place in two methods:

- A progressive screening will verbalize the specialist whether the youngster is on target with rudimentary capacities, for example, schooling, talking, exercises, and moving. Pros suggest that kids be screened for these formative deferrals all through their precise registration at 9 months, year and a half, and 24 or 30 months old enough. Kids are constantly checked decisively for mental imbalance at their 18-month and 2-year registration
- If the youngster demonstrates indications of an issue on these screenings, they will require an extra definite assessment. This may include hearing and vision assessments or hereditary tests. The specialist may have to bring someone who has practical experience in mental imbalance issues, similar to a formative pediatrician or a youngster clinician. Chosen analysts can besides give a test called the Autism Diagnostic Observation Schedule (ADOS).

2.3 Autism Treatment

There is no remedy for chemical imbalance. However, early determination can gain an extraordinary change in the ground for a kid with mental imbalance. There are two main treatments of autism. They are

- Behavioral and communication therapy. Applied Behavior Analysis (ABA) is one of these medicines, it supports positive conduct and debilitate negative conduct. Occupational therapy can help with fundamental abilities like dressing, eating, and interfacing with individuals.
- Sensory incorporation treatment can help somebody who has issues with being contacted or with sights or sounds.
- Speech treatment creates relational abilities.

3 Related Work

Omar et al. (2019) proposed a successful prescient model dependent on AI and created portable application for foreseeing mental imbalance. They have utilized Decision Tree calculation, Random Forest CART (classification and regression trees), and Random Forest-ID (Omar et al. 2019) to create mobile application to connect with parents and kids. The techniques used in this paper are as follows: (1) Leave-one-out technique is applied to check effectiveness of the proposed model (Omar et al. 2019). (2) Decision tree cart algorithm was implemented to predict autism, later Random Forest Cart is implemented (Omar et al. 2019). (3) Combining RF and RF ID3 gives better accuracy than decision tree (Omar et al. 2019). *Accuracy* of the proposed model for child is 77.26, adolescent is 79.78, and adult is 85.1[illegible]. *Specificity* for child is 75.34, adolescent is 71.6, and adult is 84.11. *Sensitivity* for child is 81.52, adolescent is 82.6, and adult is 82.07. *Precision* for child is 73.09, adolescent is 73.82, and adult is 84.54 using Random Forest CART + Random Forest–ID3.

Condy et al. (2019) describe about the study which investigates whether respiratory sinus arrhythmia (RSA) and broad autism phenotype (BAP) (Condy et al. 2019) traits in mothers of typically developing (TD) (Condy et al. 2019) children and mothers of children with ASD influence maternal affect. Gauge physiological information were gathered from 37 moms; in any case, just 35 moms (13 moms of youngsters with ASD) had full standard, assignment, and reactivity physiological information. Calculations utilized are RSA and BAP. They proposed questioner-based techniques like questionnaires with parents and parent–child interaction is recorded and their stress level is detected by using heart rate using regression model. The aftereffects of the current investigation offer starter help the speculation that RSA reactivity directs the connection between maternal BAP unbending nature and maternal effect during a difficult communication among mother and youngster. The mean HR reactivity was 3.55 (SD = 4.30) and mean lnHFHRV reactivity was −0.65 (SD = 0.85) for the 35 moms who had full physiological information.

Ibrahim et al. (2019) explain a genuine depiction audit to investigate issues and impending rules encompassing the DSM-5 explicit learning issue (SLD) (Ibrahim 2019) among school-matured youngsters with mental imbalance range issue (ASD) (Ibrahim 2019). This paper tells around: (1) Considering Specific Learning Disorder (SLD) (Ibrahim 2019) in Autism Spectrum Disorder (ASD). (2) Upgrading the scholarly advancement for ASD kids with SLD (Ibrahim 2019). Critically, a few speculative ends have been made in an audit researching RC (reading comprehension) in kids with ASD: First, kids with ASD perform better in single-word undertakings contrasted with RC—this has been ascribed to unraveling abilities. Second, oral language capacity impacts RC essentially. Third, numerous people with ASD have RC deficiencies regardless of good or unblemished interpreting aptitudes. Fourth, nonverbal social comprehensions are likewise connected with RC capacity. What's more, fifth, semantic, and linguistic information have higher relationship with RC execution contrasted and phonological preparing.

Xu et al. (2018) educate the parents to take genetic test. Classifying parents whether they agree to take test or not based on questionnaires in web based. 3. Different relapse results for the three results: information level of ASD, uplifting disposition, and negative mentality toward ASD. The autonomous factors were age, female, race (Caucasian versus others), conjugal status, training level (secondary school or underneath, some school/partner certificate, 4-year college education, and graduate/proficient certificate), and family pay level (<$39,000, $40,000–$49,000, and ≥$50,000). The fundamental result variable was whether guardians would take the youngster to go through ASD hereditary testing.

Reeta et al. (2018) examine mutations in the genes associated with autism which affects brain development and its functions, starting well before birth (Reeta et al. 2018). Heterogeneous genomes which differ from every person. It includes complex hereditary qualities etiology, DNA, and quality. It has a huge dataset with complex hereditary structures which must be taken care of to eliminate the loud and conflicting information. They proposed an approach to rank the set of diseased genes which is present in the autistic people. From the preparation informational index, the system predicts the medically introverted conduct of a person by contrasting the likenesses between the person's quality and the infected quality in the preparation set. They have used Naive Bayesian classification algorithm. They used machine learning techniques like data collection, data preprocessing, and Naive Bayesian classification and prediction (Reeta et al. 2018).

Mayilvaganan and Kalpanadevi (2015) utilized C4.5 calculation and Naive Bayes' classifier for predicting the cognitive expertise of understudies. The expertise of an understudy is tried during the online test which is related with the canny grade (IQ) and well-being which is ordered utilizing Naive Bayes algorithm.

Hollowood et al. (2018) examine pregnancy blood samples, i.e., first trimester, second trimester, and third trimester blood tests. The data is collected such that the pregnancy mother already had autism child as a first child. The techniques used are folate metabolism, transmethylation, and transulfuration to examine the blood samples. Only 18.7% is predicted. It's difficult to predict autism in pregnancy and we are not sure about results.

Nasser et al. (2019) explain about how artificial neural network model can be used to diagnose the autism spectrum disorder. Artificial Neural Network (ANN) model had the option to anticipate the class 100% precisely, with 0% for normal blunder rate. The dataset used is Fadi Fayez Thabtah Attribute Type Description which contains the following attributes: (1) ID number; (2) age, number in years (Nasser et al. 2019); (3) sexual orientation string (f, m), male or female (Nasser et al. 2019); (4) nationality string list of basic identities in content arrangement (Nasser et al. 2019); (5) Jaundice Boolean (yes or no) regardless of whether the case was brought into the world with jaundice (Nasser et al. 2019); (6) chemical imbalance Boolean (yes or no) regardless of whether any close relative has a PDD (Nasser et al. 2019); (7) connection string who is finishing the test? parent, self, guardian, clinical staff, clinician, and so on; and (8) nation of habitation string list of nations in content arrangement.

Liu et al. (2017) utilized "Response to Name Dataset" appraisal system to examine autism range issue. Created screening framework dependent on AI. Created assessment framework using ML to automatically predict the responsiveness scores. They proposed discourse acknowledgment which depends on programmed verbally abusing location; face discovery/arrangement; head present assessment; and considers the reaction speed, eye-to-eye connection span, and head direction to yield the final expectation.

Altay and Ulas (2018) explained the classification method for autism spectrum disorder diagnosis for the age group 4–11 years. The Linear Discriminant Analysis (LDA) and the K-Nearest Neighbor (KNN) calculations are utilized for arrangement. (1) KNN algorithm: In the initial step, the good ways from the new information to all information is determined. In the subsequent advance, the distances are arranged. The third step takes the littlest k qualities and the last advance decides the class. (2) Direct Discriminant Analysis (LDA) Algorithm: The LDA calculation essentially works through the estimation of change esteems inside and between classes. They have done research based on questionarie. The dataset is made up of questionarie. The yield estimations of the dataset comprise two classes. 1[illegible] distinct highlights have been named as info esteems and whether kids have ASD. 1 worth shows that the youngster doesn't have ASD, though 2 demonstrates that the kid has ASD. They tried the characterization calculation dependent on exactness, affectability, particularity, accuracy, and F-measure. They have accomplished accuracy is 0.9080, affectability is 0.9524, particularity is 0.8667, exactness is 0.8696, and F-measure is 0.9091 utilizing Linear Discriminant Analysis (LDA) algorithm. They have accomplished accuracy is 0.8851, affectability is 0.9762, particularity is 0.8000, exactness is 0.8200, and F-measure is 0.8913 utilizing K-Nearest Neighbor (KNN) calculation.

Wei et al. (2019) proposed a novel saliency expectation model for kids with mental imbalance range issue (ASD) by removing the pictures through eye staring from ASD children. Using convolutional neural networks they have explained how to extract the multilevel features from eye tracking dataset and integrated them into three consideration maps which are utilized to create the anticipated saliency maps. They analyzed foreseeing visual consideration of kids with ASD. Receive the staggered highlights got from the enlarged convolutional network (DCN) and use deconvolutional activities to upsample include maps through various ways. The guides gained from ground realities are joined with the upsampled maps by utilizing convolutional activities. The result of this exploration is (1) Proposes a novel saliency expectation model that misuses staggered highlights and profound management to adequately foresee the obsessions of youngsters with ASD. (2) To encourage the proposed model to zero in on learning the highlights of notable areas, the obsession thickness maps as the ground realities are handled by means of single-side cut-out, which further lifts the saliency forecast execution.

Zhuang et al. (2019) used to recognize basic changes in the mind after treatment and select basic highlights related with treatment results. Sure freedom screening (SIS) technique has been utilized to choose prescient highlights and precise models. The dataset utilized is 19 kids dataset (13 guys, 6 females) partook in about 4 months of PRT treatment. Methods utilized are: (1) Intelligence level was estimated utilizing the Wechsler Abbreviated Scale of Intelligence (WASI). (2) Every kid went through pre-treatment and post-treatment checks on a Siemens MAGNETOM 3 T Tim Trio scanner. A basic MRI picture arrangement was obtained with a 12-channel head curl and a high-goal T1-weighted MPRAGE grouping. (3) Prescient models performed leave-one-out cross-approval (LOOCV) and estimated cross-connection and root mean squared blunder (RMSE) among forecast and ground-truth results. We picked LOOCV rather than connection examination to approve the consistency which minimizes the false revelation rate.

Wan et al. (2019) applied eye following to distinguish the mental imbalance range problem in youngsters. In this paper, the obsession seasons of 37 ASD and 37 regularly creating (TD) kids (Wan et al. 2019) have been explored whose ages lie between 4 and 6 years by viewing a 10-s video of a female talking. They enlisted the ASD members from an outpatient ward of youngster Mental Health and Rehabilitation Center at Shenzhen Maternity and kid Healthcare Hospital in China. TD members were enlisted from kindergarten from same city. Kids were situated before a 22-in. widescreen LCD screen in a dull and soundproof room. Look designs were recorded utilizing BeGaze information examination programming framework.

Park et al. (2016) clarified about the hereditary investigation on ASD. They analyzed the complexities of qualities associated with synaptogenesis and axon motility. The obsessive changes that happen in the cerebrum of patients with ASD are recognized. Critically, the function of amygdala, a significant segment of the limbic framework, and the influencing circle of the cortico-striato thalamo-cortical circuit, in observation and ASD, have been confirmed in plentiful neuropathological and neuroimaging trainings. Additionally, core accumbens is likewise considered as the significant structure which is related with the social reaction in ASD (Park et al. 2016).

Hyde et al. (2019) depicted about an audit on directed AI in autism spectrum issue. Their paper gives an exhaustive audit of 45 papers on autism finding by utilizing managed AI strategies which incorporate calculations for characterization and examination of text.

4 ASD Research Based on Supervised Techniques of ML

The supervised learning research concentrated in this paper contains arrangement calculations considered to perceive designs in a specific dataset that will prompt a right determination or other gathering of members (Hyde et al. 2019). A considerable lot of the investigations characterized in this survey applied various different managed AI strategies (Hyde et al. 2019). Out of 15 papers remembered for this audit, Decision tree calculation irregular woodland truck (classification and relapse trees) and arbitrary timberland (Omar et al. 2019) are utilized in one investigation, regression model is utilized in one paper, multiple strategic relapse model is utilized in one examination, Naive Bayesian classification approach is utilized in two paper, C4.5 calculation and Naive Bayes' classifier are utilized in one paper, neural organization is utilized in two papers, for example, counterfeit neural organization is utilized in one paper and convolution neural organization is utilized in one paper, score forecast rule-based decision tree is utilized in one paper. The Linear Discriminant Analysis (LDA) and the K-Nearest Neighbor (KNN) calculations are utilized for grouping which is utilized in one paper, sure freedom screening (SIS) technique is utilized in one paper, and BeGaze information investigation programming is utilized to foresee eye stare in youngsters.

4.1 Decision Tree Algorithm Random Forest (RF)-Cart (Classification and Regression Trees) and Random Forest-Id

Omar et al. (2019) AQ 10 and 250 genuine dataset with and without autism is utilized. Leave-one-out method is applied to check viability of the proposed model. At that point, choice tree truck calculation was actualized to anticipate chemical imbalance, later Random Forest Cart is executed, and consolidating RF and RF ID3 gave preferred precision over choice tree.

4.2 Regression Model

Condy et al. (2019) describe about the study which investigates regardless of whether respiratory sinus arrhythmia (RSA) and broad chemical imbalance aggregate (BAP) qualities in moms of ordinarily creating (TD) kids and moms of youngsters with ASD impact maternal effect. Pattern physiological information were gathered from 37 moms; in any case, just 35 moms (13 moms of kids with ASD) had full gauge, undertaking, and reactivity physiological information. Algorithms used are RSA and BAP. They proposed questioner-based techniques like questionnaires with parents and parent–child interaction are recorded and their stress level is detected by using heart rate using regression model.

4.3 Multiple Logistic Regression Model

Educate the parents to take genetic test. Classifying parents whether they agree to take test or not based on questionnaires in web based. Multiple regression results are done for the three results, namely, information level of ASD, inspirational disposition, and negative demeanor toward ASD.

4.4 Naive Bayesian Classification Approach

Reeta et al. (2018) take a gander at changes in the characteristics related with mental unevenness which impacts emotional wellness and its abilities, starting extraordinary before birth. Heterogeneous genomes which move from each individual. It incorporates complex genetic characteristics etiology, DNA, and quality. It has a huge dataset with complex genetic structures which must be dealt with to dispose of the loud and clashing data. They proposed an approach to manage rank the plan of weak characteristics which is accessible in the intellectually lopsided people. From the planning enlightening list, the structure predicts the intellectually uneven lead of an individual by differentiating the likenesses between the individual's quality and the debilitated quality in the arrangement set.

4.5 C4.5 Algorithm and Naive Bayes Classifier

Mayilvaganan and Kalpanadevi (2015) predict the cognitive inclination of understudies. The mastery of an understudy had a go during the online test which is connected with the shrewd evaluation (IQ) and well-being which is grouped utilizing Naive Bayes algorithm.

4.6 Artificial Neural Networks

Ibrahim et al. had the option to foresee the class 100% precisely, with 0% for normal blunder rate. The informational index utilized is Fadi Fayez Thabtah Attribute Type Description which contains the accompanying characteristics: They are (1) ID number (Nasser et al. 2019); (2) age, number in years (Nasser et al. 2019); (3) sex string (f, m), male or female; (Nasser et al. 2019) (4) identity string list of basic nationalities in content arrangement (Nasser et al. 2019); (5) Jaundice Boolean (yes or no) regardless of whether the case was brought into the world with jaundice (Nasser et al. 2019); (6) chemical imbalance Boolean (yes or no) regardless of whether any close relative has a PDD (Nasser et al. 2019); (7) connection string who is finishing the test that is parent, self, guardian, clinical staff, clinician, and so forth; and 8. nation of living arrangement string list of nations in content organization.

4.7 Rule-Based Decision Tree

Liu et al. (2017) used "Response to Name Dataset" assessment framework to study autism spectrum disorder and developed screening system. Assessment framework was created using this algorithm to automatically predict the responsiveness scores. They proposed speech recognition which is based on programmed verbally abusing identification; face location/arrangement; head present assessment; and considers the reaction speed, eye-to-eye connection length, and head direction to yield the final forecast.

4.8 The Linear Discriminant Analysis (LDA) and the K-Nearest Neighbor (KNN)

Altay and Ulas (2018) KNN algorithm is utilized in initial step which figures the good ways from the new information to all information. In the subsequent advance, the distances are arranged. The third step takes the littlest k qualities and the last advance decides the class. Straight Discriminant Analysis (LDA) algorithm fundamentally works through the count of fluctuation esteems inside and between classes. They have done research based on questionarie. The dataset is made up of questionarie. The yield estimations of the dataset comprise two classes. 19 distinct highlights have been marked as info esteems and whether kids have ASD. 1 worth shows that the kid doesn't have ASD, though 2 demonstrates that the youngster has ASD. They tried the order calculation dependent on exactness, affectability, explicitness, accuracy, and F-measure. They have achieved the following: accuracy is 0.9080, sensitivity is 0.9524, specificity is 0.8667, precision is 0.8696, and F-measure is 0.9091 using Linear Discriminant Analysis (LDA) algorithm. They have achieved the following: accuracy is 0.8851, sensitivity is 0.9762, specificity is 0.8000, precision is 0.8200, and F-measure is 0.8913 using K-Nearest Neighbor (KNN) algorithm.

4.9 Convolutional Neural Network

Wei et al. (2019) extracted the multilevel features from eye tracking dataset and integrated them into three consideration maps which are utilized to create the anticipated saliency maps. They inspected anticipating visual consideration of kids with ASD and received the staggered highlights got from the widened convolutional network (DCN) and used deconvolutional tasks to upsample which include maps through various ways. The guides gained from ground realities are joined with the upsampled maps by utilizing convolutional tasks. The result of this exploration is (1) It proposes a novel saliency expectation model that misuses staggered highlights and profound oversight to successfully anticipate the obsessions of youngsters with ASD. (2) To encourage the proposed model to zero in learning the highlights of striking areas, the obsession thickness maps as the ground realities are handled through single-side section, which further lifts the saliency forecast execution.

4.9.1 Sure Independence Screening (SIS) Method

Zhuan et al. (2019) recognized primary changes in the cerebrum after treatment and selected underlying highlights related with treatment results. Sure freedom screening (SIS) strategy has been utilized to choose prescient highlights and precise models. The dataset utilized is 19 kids dataset (13 guys, 6 females) which took an interest in about 4 months of PRT treatment. Procedures utilized are (1) Intelligence level was estimated utilizing the Wechsler Abbreviated Scale of Intelligence (WASI). (2) Every kid went through pre-treatment and post-treatment examination on a Siemens MAGNETOM 3 T Tim Trio scanner. A primary MRI picture arrangement was procured with a 12-channel head loop and a high-goal T1-weighted MP-RAGE succession. (3) Prescient models: performed leave-one-out cross-approval (LOOCV) and estimated cross-relationship and root mean squared blunder (RMSE) among expectation and ground-truth results. We picked LOOCV rather than other techniques to approve the consistency which identifies the false disclosure rate.

5 Conclusion

This paper helps in surveying an autism spectrum disorder using various machine learning algorithms. It has been witnessed that machine learning algorithms are widely used and attain good performance in various applications of autism spectrum disorder analysis. This paper gives the survey of autism disorder and explanation of machine learning algorithms. Based on our research one can use any one of the supervised algorithms to diagnose any disease.

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Chapter 3
Adjustable Design Intervention for Rail Sahayakas to Reduce Physical Discomfort

Isha Deosthali, Nishant Bagmar, and Wricha Mishra

1 Introduction

The primary and preferred mode of transport still remains the railways for a large part of the population (Hariharan 2017). The Indian nationwide rail network, is the fourth-longest and heavily used system in the world, operated by the state-owned Indian railways and includes operating route length of more than 65,000 km (Kaushik 2016). The railway is the most convenient mode of transport for long distances. Railways is also the most suitable for carrying heavy and bulky goods due to no restrictions on the amount of weight a passenger can carry (Sarkar 2019).

In 2016, the Government of India declared that the "coolie"s' will be called "Rail Sahayaks" from now in order to drop the negative colonial connotation of the term. The sahayaks have been serving the passengers ever since the railways were established in India. They are the familiar figures at every city railway station who carry the passenger's luggage on their head and shoulders, making a living out of hard physical labor. The life of a sahayak is not easy and they go through a lot of hurdles at their workplace. There are approximately 20,000 licensed sahayaks in India. They aren't official employees thus come under the unorganized sector (Thakur et al. 2018).

In the Indian railways, the sahayaks are exposed to activities like pushing, carrying, lifting hefty luggage and lowering weights while adopting unnatural postures. Such situations may lead to Work-related Musculoskeletal Disorders (WMSDs) in different body regions (Khan and Singh 2018). Work-related MSDs affect the workers in a wide range of occupation gradually over months or years.

In a view of this, the objectives of this study (i) were to analyze problems faced by the Rail Sahayaks while they perform their physically exhausting work and (ii) to design an intervention that benefits the sahayaks and reduces the physical strain.

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2 Methodology

2.1 Study Design and Participants

This study was conducted with 27 sahayaks present on the Pune Station in the month of August 2019. The objectives of this study were elaborated and due consent was taken before their participation in the study.

2.2 Data Collection

A self-reported questionnaire was used to gather data among the sahayaks. The sahayaks from different age groups were interviewed and questions related to their work experience, problems related to physical strain, etc., were asked. The Railway authorities of the railway stations of Pune were also questioned regarding the norms of station with respect to the sahayaks.

2.3 Rapid Upper Limb Assessment (RULA)

RULA was developed to evaluate the exposure of individual workers to ergonomic risk factors associated with upper extremity like upper limbs, neck and back in relation to the muscular action and external loads applied to the body (Cremasco et al. 2019).

2.4 Nordic Musculoskeletal Questionnaire (NMQ)

The questionnaire comprises objective questions that involve data related to the manual load handling, preferred body part to carry/lift load, general health issues, and musculoskeletal problems in specific body parts like neck, upper back, lower back, shoulders, knees and calves. The questionnaire provides useful and reliable information on musculoskeletal symptoms.

2.5 Quick Exposure Checklist (QEC)

QEC is an easy, straightforward tool to use, which provides Exposure Scores for body areas, identifies needed exposure reduction and assists with job comparisons as well as before and after evaluations. The QEC is of value in prompting improvements and in evaluating the benefits (reduction in exposure to WMSD risk factors) by providing a structured process to help prioritize the need for change (David et al. 2008).

2.6 Workplace Ergonomic Risk Assessment (WERA)

WERA, which is an observational tool, was developed to provide a method of screening the working task quickly for exposure to physical risk factors associated with Work-related Musculoskeletal Disorders (WMSDs). WERA assessment can be done in any space of workplaces without disruption to the task that has been observed (Abd Rahman et al. 2011).

2.7 Time-Motion Analysis

Time study is a tried and tested method of work measurement for setting basic times and hence standard times for carrying out specified work. The aim of time study is to establish a time for a qualified worker to perform specified work under stated conditions and at a defined rate of working.

3 Results

3.1 Data Collection

With the help of the self-reported questionnaire, sahayaks were questioned about their hours of working, pain points, health problems, daily earnings, etc. It was found that 75% of the sahayaks were between 30 and 45 of age and 40% of them have been working for the past 15–20 years. 74% of the sahayaks have mentioned taking leave for more than 10 days per month, as they experience pain due to heavy manual lifting/loading. The data were collected on the basis of these two postures.

3.2 Rapid Upper Limb Assessment (RULA)

It is divided into two groups, Group A consists of the upper arm and wrists while Group B consists of the neck, trunk, legs and muscle score. The RULA score for both the postures is 7, indicating a need for immediate investigation and implementation.

3.3 Nordic Musculoskeletal Questionnaire (NMQ)

Most of the coolies reported the severity of pain as moderate. The primarily affected body regions were lower back (43%), neck (47%), shoulders (51%), upper back (27%) and knees (47%). We can see that the complaints for the shoulder and neck are alarmingly high.

3.4 Quick Exposure Checklist (QEC)

Through the results, it was found that the sahayaks experience the maximum pain in their shoulders. The sahayaks lifted more than 20 kgs on a daily basis for more than three times in day.

3.5 Workplace Ergonomic Risk Assessment (WERA)

Through WERA, the tasks carried out by the sahayaks were observed and analyzed to understand the exposure of the physical risk factors associated with their tasks. The final scores lie between 35 and 40, which is also high and needs immediate investigation and intervention as it's highly risky.

3.6 Time-Motion Analysis

In order to evaluate the time taken for the sahayaks to travel from a station to the exit gate with the luggage they carry, we followed 10–12 sahyaks (with their permission) from to calculate the time and observe their actions and behavior. The findings of time-motion analysis show that the sahayaks take an average of 11 min 36 s from the platform to the exit gate. It was concluded that the speed of the sahayak decreases as the weight on the body increases.

4 Design Intervention

In order to serve an engaging and easy design intervention for the sahayaks to reduce their physical strain, an adjustable trolley could be altered according to the sahayak's convenience and can be rolled over a ramp on the staircases is proposed. In the current scenario, the sahayaks don't use the trolley due to the huge size and the presence of only one slope bridge at the end of the station. The trolleys are placed at only one end of the station, which makes it difficult to arrange and roll the trolley to another end during the rush hour and festival times when a large number of passengers travel through trains. There is a need for more inclined platforms on the stations, Thakur et al also say inclined platforms facilitate ease and speed of movement of luggage (Thakur et al. 2018).

They often resist to use the trolley due to the weight and extra efforts they need to take and so they cross through the railway tracks to commute between the platforms. According to the International luggage size standards, two standard checked luggage size bags that are 27 in. × 21 in. × 14 in. each can be fitted inside the trolley easily. An adjustable handle is attached at the back of the trolley, which helps them to adjust the height of it according to their convenience. Mechanisms are also provided for latching the trolley for luggage transfer and loading. The trolley is designed in order to give the sahayak a helping hand for carrying the heavy weight easily through the platforms of the station.

The design proposed helps facilitate easy movement of luggage and minimize the awkward situations and continuous physical contact.

5 Discussion

In India, the issues and the occupational health facilities of the workers working in the unorganized sector are given limited importance. Various organizations around the world have performed investigative studies on the possible effects of manual material handling on different body parts, but no such study had been conducted on railway sahayaks in India before (Khan and Singh 2018). Workers are exposed to heavy physical tasks working which further creates an unhealthy environment. Consequently, it causes fatigue in sahayaks after carrying out such tasks (Vøllestad 1997; Nur et al. 2015).

The present study represents problems of work-related musculoskeletal disorders faced by the sahayaks and the risk factors associated with it. The analysis was done on two major postures of the sahayaks (Fig. 1). It was found that major affected

Posture A *Posture B*

Fig. 1 Postures A and B represents constant postures of the sahyaks body regions were neck (52.9%), shoulder (64.7%), lower back (41.2%) and knee (47.10%) as shown in Fig. 2. The RULA score for most of the coolies was 7 (Table 1), which was found to be in agreement with a study of workers in manual brick-laying kiln by Qutubuddin et al. (Maulik et al. 2014). The 12-month prevalence of MSDs was 79% in a study conducted among 200 waste pickers in Mumbai by Singh et al. (Qutubuddin et al. 2013), which is lower than the NMQ analysis (Fig. 3), which was conducted on the sahayaks. In order to get more insights, QEC (Fig. 4) and WERA (Fig. 5) were conducted as they are observational tools, developed to provide a method of screening the working task quickly for exposure to physical risk factors associated with MSDs. The insights through this make it very evident that the sahayaks experience the highest level of pain in the shoulders. The average

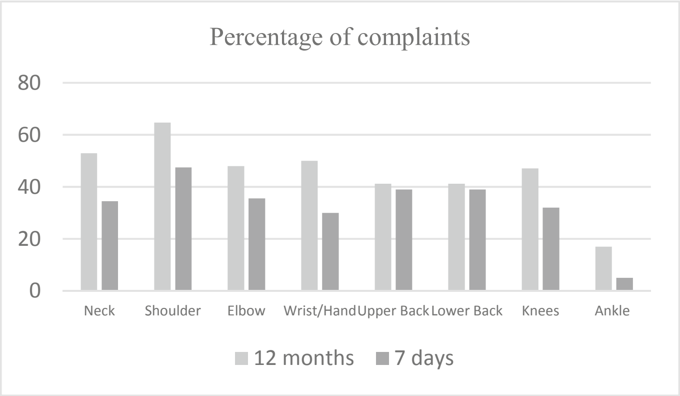

Fig. 2 Represents the percentage of complaints the sahayaks mention in the past 12 months and 7 days regarding the areas of pain during work

Table 1 Represents the data found from RULA

Postures	Posture A	Posture B
Upper arm	6	5
Lower arm	3	3
Wrist position	3	3
Wrist twist	1	1
Final A	9	7
Neck	1	2
Trunk	1	2
Leg	1	1
Muscle score	1	1
Force/load score	1	3
Final B	5	6
Final RULA	7	7

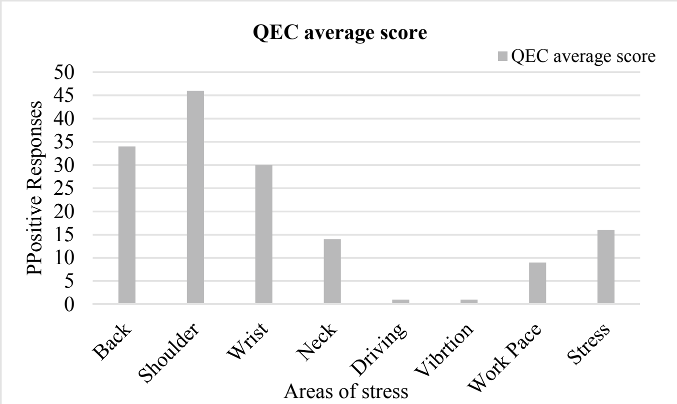

Fig. 3 Represents the average score of Quick Exposure Checklist, which was conducted during the survey

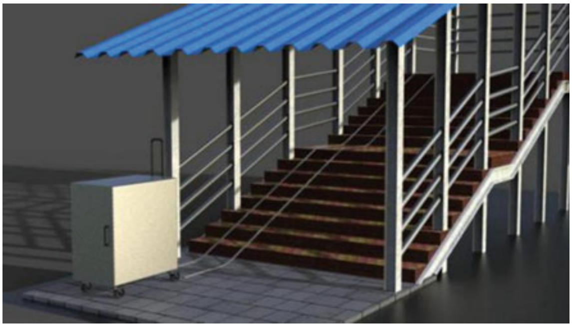

Fig. 4 Represents an insight into how the trolley would work with the ramp

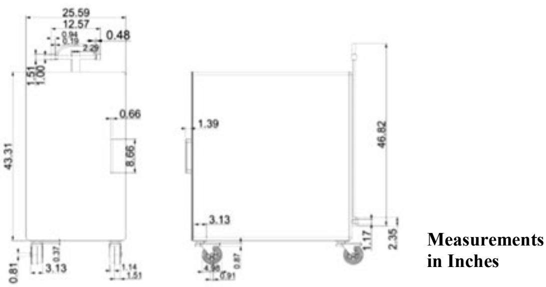

Fig. 5 Shows the insight of how the trolley would work with the measurements

time required for a sahayak takes almost 11 min to reach the exit from the nearest platform, same have been mentioned in the results conducted through Time-Motion Analysis (Table 2).

A study revealed that inappropriate design of a mechanical aid results in changes of postures, leading to higher muscular loads during pushing activity (Singh and

Table 2 Represents the data derived from WERA

Postures	Posture A	Posture B
Shoulder	6	6
Wrist	3	3
Back	4	4
Neck	4	4
Leg	3	5
Forceful	4	6
Vibration	3	3
Contact stress	3	3
Task duration	5	5
Final score	35	39

Chokhandre 2015). Consequently, they suffer from severe musculoskeletal disorders (MSD), which not only hinder them physically but also enhance their mental agony. The need of the time is to improve the design to prevent the MSDs and improve efficiency so that they start using it on a regular basis.

When stairs are considered, normal hand trolleys fail. To overcome this, a staircase climbing trolley that can carry heavy objects up the stairs helps with comparatively less effort than to carry them manually (Ajay et al. 2017). Introducing an adjustable trolley will reduce the physical stress experienced by the sahayaks, which was consistent with the findings of Burdorf et al., which shows that the introduction of new mechanized equipment resulted in changes in physical load/task within jobs, changes in task distribution within jobs and changes in work organization and jobs within a team (Burdorf et al. 2007).

The design of the trolley is closed-packed, solid and firm due to which it's able to move about in almost all the stairs on the platform. The advantage of the project is the decreasing effort due to stair climbing mechanism for the load carrier. We believe that the present invention meets those needs by providing an adjustable roll-in trolley having adjusting mechanisms, which require less maintenance than previous designs and which will operate smoothly and consistently in use.

6 Conclusion

Through the study conducted, it was concluded that the sahayaks are subjected to high risk of musculoskeletal disorder. The reason behind the prevalence may be the need of carrying heavy loads and adoption to awkward postures for their daily livelihood. The primary affected body regions are neck, lower back, shoulder, knee and ankle/feet. There have been various investigative studies on the possible effects of manual material handling but no such study had been conducted on railway sahayaks in India before. There isn't awareness about the musculoskeletal pain that can lead to serious injuries leading to accidents on the platforms and could also result in long-term effects on their bodies. Hence, with the introduction of an adjustable trolley and ramp on the platforms of the station, we aim to reduce the risk of MSD's in sahayaks and also enhance the efficiency of their work. Additionally, the sahayaks may gain more passengers by a ramp being present, which will decrease the time a shayak takes to commute on the platform. This will result in an increase in their earnings without being exposed to MSD's and their risk factors.

7 Limitations

Limited interviews were conducted as the place of study was selected as per the convenience, so the occurrence of MSDs in railway sahayak cannot be generalized. Further study should be performed on a larger population based on sahayaks working in different regions of India in order to find out a more generalized trend of MSDs for the implementation of necessary preventive measures.

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Chapter 4
An Ergonomic Study of the Cleaning Workers to Identify the Prevalence of Musculoskeletal Disorders in India

Neelesh K. Sharma, Mayank Tiwari, Atul Thakur, and Anindya K. Ganguli

1 Introduction

The size of the labor force is approximately 521.9 million, in an overall population of around 1.3 billion in India, of which 94% works in the unorganized sector under minimum wage (Das 2017). Mechanization and industrial development have reduced the worker's effort, but the unorganized sector is still dependent on manual labor for innumerable activities and jobs. Regular works of material handling, repair, and maintenance are performed manually in developing countries like India.

Administrative and waste service is a sector that works for the removal of dirt and dust, and waste collection and management with the help of manual labor. It is one such sector where a lack of resources, planning, and leadership are the bottlenecks in achieving effective waste management, which puts a considerable strain on the municipal workers for maintenance (Nandan et al. 2017). With India plying to attain the status of an industrialized nation by 2020, industrial development and population explosion provide a favorable condition for an exponential increase in the dirt, dust,

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and solid waste (Sharma and Jain 2019). Workers in this sector suffer from respiratory diseases, dermatological problems with the prevalence of musculoskeletal morbidities (Thakur et al. 2018).

Musculoskeletal disorders (MSDs) are the pain or agitation in the muscles, joints, cartilage, tendons, and nerve and are generally found in the lower back, neck, and limbs (Gallagher and Schall 2017). The main factors for MSDs are repetitious motions, forceful exertions, uncomfortable posture, and stationary position for an extended period. Work-related musculoskeletal disorders are identified and accepted to converge the focus to industrial workers and take time in months or even years to grow and hamper workers (Khan et al. 2019).

Nordic Musculoskeletal Questionnaire (NMQ) is one of the most common tools used for the identification of risk related to musculoskeletal disorder. It was developed by Kuorinka et al. with funding from the Nordic Council of Ministers (Kuorinka et al. 1987). Its main aim was the study of complaints related to pain in different body parts for use in epidemiological studies. A General Nordic Questionnaire consisted of two parts: (a) demographic characteristics and (b) musculoskeletal disorder specifications. Demographic characteristics included information related to gender, age, body mass index, marital status, hobbies. Simultaneously, the second part of the questionnaire extracted information pertaining to musculoskeletal disorders in different body parts over the last 12 months (Daneshmandi et al. 2019).

Heart rate is another measurement tool that can act as a suitable physiological index for assessing the workload and performance of a worker (Cureton and Kasch 1947; Tomlinson and Manenica 1977). Heart rate can be measured continuously under field conditions using a heart rate monitor. An average heart rate can then be utilized for the categorization of workload from the light to extremely heavy (Nag and Chatterjee 1981; Sen 1969; Varghese et al. 1994). This method was previously used for assessing physiological workload in many sectors like mud transfer activity (Kundu et al. 2019), driving vehicle (Shakouri et al. 2018), construction worker (Roja et al. 2016), operating farm equipment (Choudhary et al. 2018).

The Three-Dimensional Static Strength Prediction Program (3DSSPP) is a software-based assessment tool developed to estimate the biomechanical and static strength capabilities of a worker concerning its workspace. It was developed at the Centre for Ergonomics at the University of Michigan College of Engineering to examine manual materials-handling tasks (University of Michigan 2018). In this method, the worker is videotaped in real time from different views while being engaged in the actual working condition. This video is then studied in a frame by frame pattern and replicated in 3DSSPP. The software then helps to identify awkward posture by estimating the percentage of the population of the workforce capable of working in such an unnatural posture.

Rapid Entire Body Assessment (REBA) (Hignett and McAtamney 2000) is an observational assessment method that analyzes the working posture of the subject. The pose is analyzed by dividing the body into two groups, namely, group A (trunk, neck, and legs) and group B (upper arms, lower arms, and wrists). The score is provided to each group based on the relative position of the body parts in it, which is then used collectively to obtain score C. Adding activity score to score C gives the final REBA score in the range of 1–15, based on which an ergonomic intervention is suggested from the five action levels.

In municipal cleaning, workers are directly involved in extreme physical activity and strenuous work in a harsh working environment. The risk of WMSDs even worsens for countries with middle and low income due to labor-intensive systems, minimal regulatory framework, underage workers, inadequate tools, and heavier loads to lift (Yovi and Yamad 2019). According to the nationwide annual cleanliness survey, 'Swachh Survekshan 2020', Patna, Bihar emerged as the dirtiest city in India (Ministry of Urban Development 2020). In order to acknowledge, evaluate, and give due emphasis to the health risks associated with the cleaning jobs, this study was conducted among workers in Bihar state, India. The results of this study will supposedly help in formatting and executing ergonomic interventions that could help in the redesign of working tools and workplaces for the overall upliftment of the working condition for the manual workers.

2 Methodology

2.1 Participants

A total of 115 workers in the Patna district, Bihar, working as cleaners, were selected for the questionnaire. Ninety-four of the total workers (men and women) population participated in this study. The inclusion criterion used was that the worker should be above the age of 18 years and have at least 12 months of continuous experience as a cleaning worker as the questionnaire investigates the incidents in the last 1 year. Based on the above criteria, two workers were excluded from the survey. Prior permission was taken from the area supervisor before conducting the experiment. Ethical Guidelines given by the Indian Council of Medical Research were followed for conducting experiments on human subjects (ICMR 2017).

2.2 Data Collection

(1) *Measurement of physical parameters*

Weight was measured using a weighing scale (HealthSense, India) with a maximum capacity of 180 kg and an accuracy of 0.1 kg. Stature was taken on a flat base using a stadiometer (PrimeSurgicals, India) with a top measuring capacity of 200 cm and an accuracy of 0.1 cm. Body mass index (BMI) was calculated using the Quetelet's Index,

$$BMI = W/H^2 \tag{1}$$

where, W is the weight in kilograms, and H is the height in meters of the cleaning workers (Garrow and Webster 1985). BMI categorization for Asian Indians was used, which suggests BMI $\geq$ 25 kg/m^2 as obese (Poskitt 2000).

(2) *Questionnaire*

The questionnaire was structured in two parts, namely, demographic and musculoskeletal sections. Reliability and validity tested Hindi version of the questionnaire was used for a better understanding of the workers (Gupta 2018). The questionnaire was briefly explained, and written consent was taken from all the workers before conducting the discussion. The participants were interviewed on a one-on-one basis, and the session lasted for about 10 minutes. Participation was voluntary, and the workers were free not to respond to any question or withdraw from the session. Helsinki guidelines were followed for data collection (World Medical Association 2013).

(3) *Body map*

The body part affected as a result of WMSDs was identified using Corlett and Bishop's body map (Corlett and Bishop 1976), and its intensity was marked using the 10-point Body Part Discomfort Scale (BPDS) (Das and Gangopadhyay 2011). Workers were asked to point out the location of pain on the body map along with the level of discomfort on the visual scale.

(4) *Posture analysis*

Seven of the workers involved in the roadside cleaning activities were selected for further analysis. Photography and video recording (Nikon J7 camera) of the working operation were conducted.

(a) Software-based analysis

3DSSPP software was used for the biomechanical analysis of the working posture. Data of the 92 workers were used for the generation of the population for study. Anthropometric data of the workers were used to prepare the humanoid. The posture attained by the worker during the cleaning activity was then replicated onto the humanoid.

(b) REBA chart-based posture analysis

Photos and videos were taken of the workers while at work and were analyzed for identifying the critical repetitive posture. The posture was then evaluated based on the score table to get the final REBA score.

(5) *Heart rate measurement*

The heart rate of the workers was measured continuously throughout the work cycle by a chest strap-based heart rate monitor (Wahoo TICKR, Model SHRM1G). The experiment started with attaching the heart rate monitor to the worker (Fig. 1).

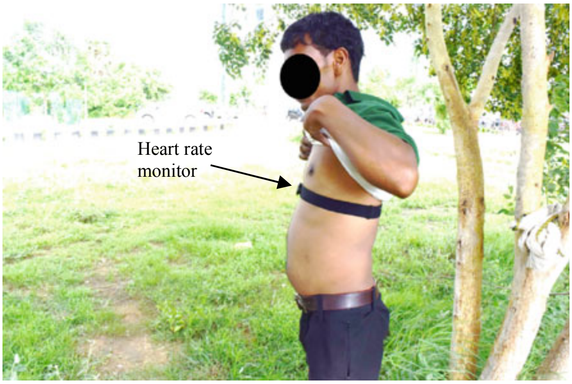

Fig. 1 Chest strap type heart rate monitor attached to the worker

It was secured for the whole duration of the investigation as the frequent removal of the device may alter the connection and reading. Ten-minute rest was provided to the worker in the shade, and the average resting heart rate was then measured for 3 minutes. During the working period, the heart rate gets stable after 3–5 minutes, so the average working heart rate was measured from the 6th minute onward to the 15th minute. Energy expenditure rate (EER) was calculated using (2) (Saha et al. 1979)

$$EER = (HR - 66)/2.4 \tag{2}$$

where, EER, kJ/min; and HR, heart rate in beats per min (bpm). All the readings for heart rate were taken in cloudy weather (32 ± 2 °C) in morning and evening shifts to reduce the effect of thermal stresses.

2.3 Statistical Analysis

Data gathered through questionnaires and measurements were arranged through Microsoft Excel 2016 and statistically analyzed through the R programming language (Foundation 2018). Tests were conducted with a 95% confidence interval, and $p < 0.05$ was considered statistically significant. The prevalence of WMSDs was determined for each body part, as well as the pain frequency and severity were also studied. Correlation between demographic characteristics and WMSDs was established using the chi-square test.

3 Results

3.1 General Characteristics

The findings from the demographic part of the questionnaire were summarized in Table 1. Most of the workers, 41.30%, were in the 31–38 years age group, and 46.74% in the normal (18.5–22.9) BMI category. More than half of the workers had a literacy level of high school and above (51.09%) and had work experience of four years and above (58.7%). Less than one-third of the population had a habit of tobacco consumption (29.35%) and exercise (30.43%) (Table 2). Exercise habits, gender, and marital status were found to be significantly associated with the risk of developing MSDs.

The feedback-based study also revealed that musculoskeletal disorder risk was prominent among workers, reported majorly in the lower back (48.39%), knee (31.18), and neck (24.73) (Table 3). BPDS-related study showed that the highest level of discomfort was concentrated on the back and shoulder of the worker.

Heart rate measurement exhibited an average resting heart rate for all the workers as 82 ± 11 bpm. Working heart rate on an average rose to 114 ± 12 bpm during the 15 min work cycle. The energy expenditure rate, as given by (2), was found to be increasing from 6.49 kJ/min at rest to 19.88 kJ/min during the working period.

The cleaning activities of the workers were divided into three sub-segments and were studied separately to provide the necessary focus on each type of task. These segments consisted of sweeping through the long broomstick (Fig. 2), dumping dirt collected through the dustpan (Fig. 3), and removal of mud and grass with a spade (Fig. 4). The results of the ergonomic assessment are summarized in Table 4.

Sweeping with the long broomstick was used for the collection of waste on the sides of the pathways. This action was repeated continuously for a minimum of 2 hours daily. It includes repetitive strokes of the broom to move the dirt and solid wastes from the center to the side of the path. The heart rate measurements showed a rise of 20 ± 1 bpm during the work cycle. Through 3DSSPP software, this posture was found to be suitable for most (98%) of the population with maximum strain in the hip joint. The REBA score for the posture attained was 6.

Dumping collected dirt and solid waste materials through the dustpan was the second segment of the study. In this category, the worker's posture was usually squatting or bending with fewer hand movements. Waste accumulated in the previous subsegment was collected through the scooping action of hand into the dustpan and then dumped into the nearest collection point. This action was performed in addition to the sweeping action and usually repeated for an average of 20 min in the whole day. An increase of 31 ± 3 bpm was found in the heart rate if the sweeping activity was incorporated with dumping action. This posture was suitable for only 80% of the population, with maximum strain in the knee area. The REBA score for this posture was 10.

The third categorization included scraping off mud, dried bird droppings, and grass from the pathway. A spade, floor scraper, and hand hoe were generally used

Table 1 Demographic and occupational profile summary of the workers

Independent factor	Total ($N = 92$)		Statistical mean and SD	
	n	%	μ	σ
Age (years)			40	7.92
<31	11	11.96		
31–38	26	28.26		
39–47	38	41.30		
>47	17	18.48		
Gender				
Male	57	61.96		
Female	35	38.04		
Marital status				
Married	88	95.65		
Single	4	4.35		
Body mass index (BMI)			22.7	3.26
<18	5	5.44		
18–22.9	43	46.74		
23–24.9	25	27.17		
>25	19	20.65		
Hand domination				
Left hand	6	6.52		
Right hand	86	93.48		
Tobacco consumption				
No	65	70.65		
Yes	27	29.35		
Education level				
Illiterate	23	25.00		
Primary school	22	23.91		
High school and above	47	51.09		
Work experience			3.76	0.94
<3	12	13.04		
3–4	26	28.26		
>4	54	58.70		
Exercise habit				
No	64	69.57		
Yes	28	30.43		

Table 2 Association between worker's profile and WMSDs reported

Independent factor	WMSDs reported						T	*p*-value
	No	%	Yes %	%	Total	%		
Age (years)							5.4133	0.1439
<31	4	36.36	7	63.64	11	11.96		
31–38	5	19.23	21	80.77	26	28.26		
39–47	6	15.79	32	84.21	38	41.30		
>47	7	41.18	10	58.82	17	18.48		
Gender							4.8392	0.0278*
Male	18	31.58	39	68.42	57	61.96		
Female	4	11.43	31	88.57	35	38.04		
Marital status							5.9985	0.0143*
Married	19	21.59	69	78.41	88	95.65		
Single	3	75.00	1	25.00	4	4.35		
Body mass index (BM1)							2.6249	0.4531
<18	0	0.00	5	100.00	5	5.44		
18–22.9	9	20.93	34	79.07	43	46.74		
23–24.9	7	2S.00	18	72.00	25	27.17		
>25	6	31.58	13	68.42	19	20.65		
Hand domination							0.3131	0.5758
Left hand	2	33.33	4	66.67	6	6.52		
Right hand	20	23.26	66	76.74	86	93.48		
Tobacco consumption							0.6112	0.4343
No	17	26.15	48	73.85	65	70.65		
Yes	5	18.52	22	81.48	27	29.35		
Education level							3.4686	0.1765
Illiterate	4	17.39	19	82.61	23	25.00		
Primary school	3	13.64	19	86.36	22	23.91		
High school and above	15	31.92	32	68.08	47	51.09		
Work experience							0.6801	0.7117
<3	4	33.33	8	66.67	12	13.04		
3–4	6	23.08	20	76.92	26	28.26		
>4	12	22.22	42	77.78	54	58.70		
Exercise habit							5.2278	0.0222*
No	11	17.19	53	82.81	64	69.57		
Yes	11	39.29	17	60.71	2S	30.43		

Table 3 Reported WMSDs distribution in the body of the worker

Body regions	Frequency (N)	Percentage (%)
Neck	23	24.73
Shoulder	17	18.28
Upper arm	13	13.98
Upper back	21	22.58
Lower back	45	48.39
Forearm	13	13.98
Thigh	19	20.43
Knee	29	31.18
Lower leg	22	23.66

*Significant at $p < 0.05$

Fig. 2 Sweeping activity of the **a)** worker replicated on the **b)** humanoid

for this. This activity required forced repetitive action, water, or a specialized tool for removing dried-up wastes. Heart rate increased by 47 ± 2 bpm during the 15 min scraping work cycle. 3DSSPP showed that strength-wise, 96% of the worker population was capable of performing this task. The final REBA score for scrapping activity was found to be 11.

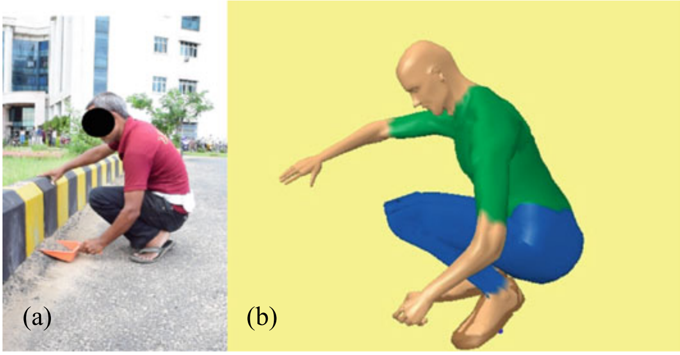

Fig. 3 Dumping activity of the **a)** worker replicated on the **b)** humanoid

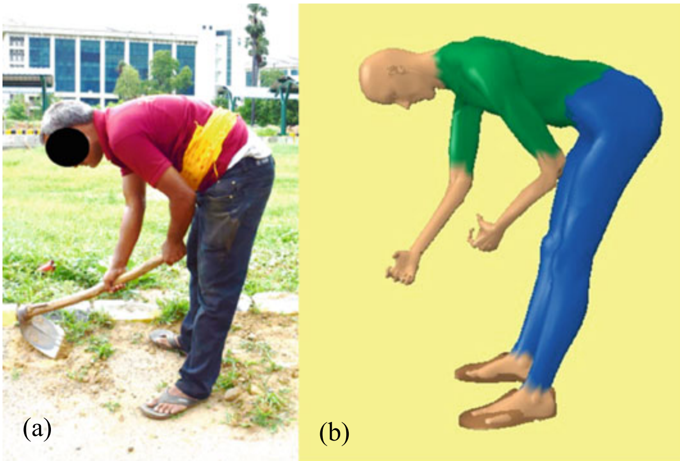

Fig. 4 Scraping activity of the **a)** worker replicated on the **b)** humanoid

Table 4 The output of ergonomic assessment of cleaning task

Task	Working heart rate above rest (bpm)	REBA score	Back compression force (N) for worker in population		
			5th percentile	50th percentile	95th percentile
Sweeping	20 ± 1	6	571	698	828
Sweeping with dumping	31 + 3	10	927	1281	1662
Scraping	47 + 2	11	1098	1478	1875

4 Discussion

In India, the health issues related to unorganized sector workers are given low importance, and medical provisions provided are limited (Khan and Singh 2018). A detailed ergonomic evaluation is warranted for redesigning equipment and workplace customized according to the worker population. This ergonomic study attempts to give due attention to the unnatural working condition of the cleaning workers.

Anthropometric data were accumulated for the worker population. The height and weight of the workers in this paper were statistically relatable with the overall average worker's body parameters in India (Chakrabarti 1997). The average BMI of the workers was in the normal range, but the BMI classification showed that 28.57% of workers were in the underweight range, and 14.29% were in the overweight range. This can be linked to the differences in the working environment, as some of the workers were working indoors and were not exposed to heat stress and pollution outside.

The data-based questionnaire study revealed the high risk of musculoskeletal disorders as the symptoms of WMSDs get prominent over time. More than half of the workforce had above 4 years of experience in service and have an even higher risk of developing WMSDs for a lifetime. Recurring pain was experienced by workers involved in activities of manual material handling. A positive trend was also noticed among workers engaged in daily exercise or have a habit of it. They were almost free from disorders, or very low intensity of pain was found in them.

BPDS revealed that body pain was deeply integrated with the cleaning work. The lower back, knee, and neck were among the severely affected zone in the body, and these pain locations showed a close association with long work cycles and working posture. Discomfort scale ratings ranged from 5 to 7 for these locations and were in the form of continuous moderate pain in the body.

Posture analysis through 3DSSPP proved to be very useful in evaluating work suitability based on worker capability and identifying body parts under maximum stress. The sweeping activity was performed continuously in standing posture, so above 90% of the workers were capable of performing the task. Dumping activity involved squatting position, which causes additional pressure on the knees. This explains the reduced strength percent capability for workers as eighty only. This posture was acquired only once in 5 min during the work cycle. Scraping activity required a great effort to be intermittently applied, which explains the pain in the lower back to shoulder in the workers associated with this working activity. Posture analysis through REBA chart-based assessment also revealed a similar pattern. Sweeping activity posture was scored at six on the REBA scale, which signifies medium risk and suggests to investigate and implement a necessary change. This score quantifies the exertions due to repetitive twisting motions involved. Dumping activity involved the squatting posture along with scooping action by hand, which resulted in a score of 10 on the REBA scale. For the third activity of scraping the mud, the REBA score was even higher than the previous ones at 11. The scores of 11+ signify very high risk and require an immediate change in the working posture. These activities were not performed continuously for longer durations by the workers and needed occasional rests in between. High REBA and biomechanical scores suggest the relatable cause for such rests.

Heart rate measurements provided concluding proof for the rating of work. As per the workload classification based on the heart rate measurements, sweeping activity came under light workload, dumping action required moderate work, while scraping activity was a physiologically heavy workload (Sen and Nag 1975). Scraping activity was performed with frequent rests between works due to the high energy requirement associated with it.

Sub-categorization of the operational activities was found to be an acceptable way of giving pivotal attention to them. Such type of classification is necessary for all the jobs that include an extensive labor force so that their duration and frequency can be monitored separately.

The results are consistent with the recent studies; janitors in Minnesota (Schwartz 2019), sanitary workers in Egypt (Abdefatah and El-mouty 2018), cleaning professionals in Porto (Santos et al. 2019), the waste collector in Iran (Ziaei et al. 2018). More such studies are warranted to incorporate customized (India specific) interventions as there can be variations in (a) the rate of waste generation, (b) mechanization involved in the cleaning sector, (c) environmental condition of the locality, (d) tools and equipment used, and (e) anthropometry and strength of cleaning staff.

5 Conclusion and Recommendation

In the labor-extensive developing countries like India, ergonomics-related evaluation is not given appropriate seriousness and is often excluded during the design of the workplace. This study highlights the severity of the health issues related to manual cleaning operations. Salient findings from this study are suggested below.

(1) All types of activities during the cleaning operation should be studied separately.
(2) High MSD risk was associated with the cleaning activity.
(3) The lower back, knee, and neck were the majorly affected body parts and were more prone to MSDs.
(4) Gender and exercise habits were found to be significantly associated with MSDs.
(5) Scraping and sweeping with dumping activities were identified as the tasks with a heavy workload.

In order to collectively reduce the risk of MSDs, some suggestions are also included in this study. These suggestions are based on direct observation and feedback from the cleaning workers and can be included as ergonomic interventions. Ergonomic interventions suggested for cleaning activities are listed below.

(1) Job rotation can be applied to reduce monotony and stress accumulation.

(2) A mechanized manipulator can be used for simplifying the task of waste scraping, picking, and dumping.
(3) Exercise and yoga programs can be organized to improve the overall health and wellness of the workers.
(4) Safety gear, including gloves, caps, shoes, and masks, can be provided to improve the working conditions.
(5) Ergonomic standards must be communicated, incorporated, and checked periodically.
(6) Long stiff fibers in the broomstick and a dedicated scraping tool can be arranged.

For future works, a study is required involving a larger sample of workers and for a longer span to observe the musculoskeletal disorder developed over time. Waste manipulators and redesigned tools should be implemented and studied separately with more depth and detail.

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Chapter 5
Analysing Metabolic Heat Among Metal Casting Workers Using Different Body Surface Area Estimates: A Comparative Study

Milap Sharma, N. M. Suri, and Suman Kant

1 Introduction

Metal casting workers are exposed to hot and humid work conditions due to the high heat industrial work environment, which are mostly subjected to intensive physical workload, having significant thermal stress on the workers' health (Krishnamurthy et al. 2017). There are several environmental factors (temperature, humidity, air velocity and radiation) and personal factors (clothing worn, muscular activity), which affect the thermal ambiance of a person (The Six Basic Factors 2020). Figure 1 describes the factors affecting heat stress exposure among workers. One such important factor is metabolic rate, which depends on the physical work activity performed by an individual in a particular work environment. Human body produces heat even at relaxed position and the rate at which heat is produced is expressed in terms of metabolic rate (in Met); where 1 met is equal to 58.2 W/m^2 (DEA3500 2020). In foundries, there are various work activities such as high-heat furnace work operations, manual material handling, manual molding, and fettling operations, which requires higher level of physical work activity. High-heat work environment imposes thermal stress, which causes thermophysiological effects on the workers body (such as rise in core body temperature, heart rate and increased sweating). An individual involved in an intensive physical work builds up body heat, expressed in terms of metabolic heat (in watts), which may be evaluated by multiplying the metabolic rate with the body surface area (BSA). BSA is the calculated surface area of a human body, which provides a better indication of metabolic mass than considering body weight and body mass index, as it is least influenced by abnormal adipose mass (DuBois and DuBois 1916). BSA estimate is beneficial in evaluating the energy requirements, while performing heat stress analysis for particular environment, with higher ambient

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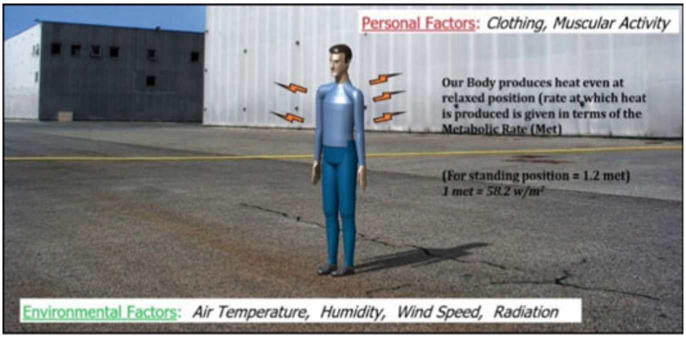

Fig. 1 Factors affecting the heat stress exposure among workers

temperatures. In high-heat work environment, evaluating BSA yields a better estimation of the thermal environment suitability for the targeted audience; which yearns a better estimation of the heat stress and thermal comfort evaluations (Ioannou et al. 2019; Zamanian et al. 2017). Its application includes evaluating the metabolic heat generated from human body while performing a physical activity (ranging from light to moderate), and evaluating cardiac index (which involves measuring the cardiac output divided by BSA), which, in turn, yields better estimate for the effective cardiac output and other medical investigations (DuBois and DuBois 1916; Gurney 2002). Although there are also few evidence that BSA values are least accurate at certain situations (like extremes of weight, height), where Body Mass Index (BMI) may be a better estimate (Adler et al. 2012). Similarly, basal metabolic rate (BMR) provides an estimation for the daily energy expenditure requirements (in Kcal) for maintaining healthy body weight based on the physical work activity level (McNab 1997; Ballesteros et al. 2018). These estimates may be considered as an effective tool in evaluating metabolic heat energy and further analyzing the thermal ambiance for a work environment. The present study intends to evaluate different BSA estimates from a group of casting workers followed by calculating the metabolic heat.

Furthermore, a comparative analysis between the estimates has also been performed.

2 Methodology

In the present study, an anthropometric survey was conducted among 87 workers employed in small- and medium-scale gray cast iron foundries located nearby Chandigarh region in India, which were further used to evaluate the BSA and BMR estimates using different expressions as described in Table 1. These estimates were utilized in evaluating the metabolic heat generated during different physical work activities and also the energy expenditure requirements for the targeted audience. A descriptive and inferential statistics has been performed using IBM SPSS 26 on

Table 1 Different expressions for evaluating body surface area (BSA) and basal metabolic rate (BMR)

BSA	Du-Bois and Du-Bois (1916)	$0.20247 \times H\ (\text{in m})^{0.725} \times W\ (\text{in kg})^{0.425}$
	Mosteller (1987)	$0.016667 \times H\ (\text{in cm})^{0.5} \times W\ (\text{in kg})^{0.5}$
	Haycock et al. (1978)	$0.024265 \times H\ (\text{in cm})^{0.3964} \times W\ (\text{in kg})^{0.5378}$
	Boyd (1935)	$0.0003207 \times H\ (\text{in cm})^{0.3} \times W\ (\text{in grams})^{0.7285 - (0.0188 \times \log(\text{weight}))}$
	Gehan and George (1970)	$0.0235 \times H\ (\text{in cm})^{0.42246} \times W\ (\text{in kg})^{0.51456}$
BMR*	Harris–Benedict 1919 (Harris and Benedict 1918)	$66.5 + (13.75 \times W\ (\text{in kg})) + (5.003 \times H\ (\text{in cm})) - (6.755 \times A\ (\text{in years}))$
	Harris–Benedict 1984 (Roza and Shizgal 1984)	$88.362 + (13.397 \times W\ (\text{in kg})) + (4.799 \times H\ (\text{in cm})) - (5.677 \times A\ (\text{in years}))$
	Harris–Benedict 1990 (Mifflin et al. 1990)	$(10 \times W\ (\text{in kg})) + (6.25 \times H\ (\text{in cm})) - (5 \times A\ (\text{in years})) + 5$

*For male participants; H: Height; W: Weight; A: Age

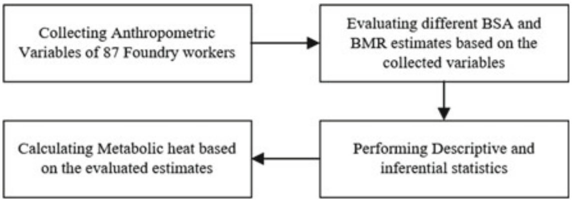

Fig. 2 Work flowchart for the present study

the BSA and BMR estimates. Figure 2 describes the work flowchart for the present study.

2.1 *Body Surface Area (BSA) and Basal Metabolic Rate (BMR)*

There are various mathematical expressions available based on previous research studies that may be utilized in determining the BSA estimates (generally expressed in m^2) involving indirect measurements utilizing weight (in kilograms) and height (in centimeters). One such frequently used expression is Du-Bois BSA estimate (DuBois and DuBois 1916). There are few other expressions, which are also commonly used including Mosteller, Gehan-George, Haycock, and Boyd BSA estimates (Mosteller 1987; Haycock et al. 1978; Boyd 1935; Gehan and George 1970; Shuter and Aslani 2000; Fujimoto et al. 1968; Schlich et al. 2010; Lipscombe 2020). Basal metabolic rate presents the energy expenditure requirements based on several factors like age, weight, and height. Most widely used BMR expression is given by Harris-Benedict

(Harris and Benedict 1918; Harris 1919), which was further modified by other researchers during later time frame (Roza and Shizgal 1984; Mifflin et al. 1990). Table 1 depicts the different BSA and BMR expressions used in this study.

2.2 Anthropometric Survey

In this current study, an anthropometric survey was conducted among 87 foundry workers to measure anthropometric variables such as stature and weight, which were further utilized to evaluate the BSA using Du-Bois and other available BSA expressions. Similarly, BMR estimations were calculated based on the three BMR expressions. Further, statistical analysis was performed on the evaluated data using descriptive analysis, scatter plots, and Pearson product–moment relationship.

2.3 Metabolic Rate

ISO 8996 standard provides information about the metabolic rate (in W/m^2) based on the physical work activities/ job occupations (ISO 8996 2004). From the product of the evaluated BSA estimates and metabolic rate, the metabolic heat generated (in watts) from the analyzed subject may be evaluated. This estimation may be beneficial in performing further heat stress analysis for a particular work environment, yielding better results. Table 2 describes the metabolic rate for workers employed in high heat work environments like iron and steel casting industries, based on the ISO 8996 standard.

Table 2 Metabolic rate based on the ISO 8996 standard (ISO 8996 2004)

Serial number	Work occupation	Metabolic rate (W/m^2)
1	Blast furnace worker	170–220
2	Electric furnace worker	125–145
3	Hand molding worker	140–240
4	Machine molding worker	105–165
5	Foundry man	140–240

3 Results and Discussion

The descriptive analysis was performed using IBM SPSS 26.0 software package. Table 3 depicts the mean and standard deviation for the weight, age, height, BMI, and Du-Bois body surface area. The descriptive statistics results for the evaluated BSA expressions have been shown in Table 4, whereas Table 5 describes the results for three different BMR expressions (in Kcal/min). The average body mass index (BMI) was found to be 23.62 kg/m^2 (ranging between 17.52 and 30.76 kg/m^2) and workers' average BSA based on the Du-Bois estimation was found to be 1.7795 m^2 ranging between (1.467 and 2.124 m^2).

Further, Pearson's product-moment correlation analysis was performed on the considered BSA and BMR estimates separately (as described in Tables 6 and 7). From the results, it was observed that there was a strong association between the Du-Bois and Mosteller BSA estimates (correlation coefficient (r) = 0.993, at 0.01 significance level). Du-Bois BSA estimate was also found to be strongly correlated with other BSA estimates. Although the BMI index showed a better association

Table 3 Descriptive statistics for analysed variables

Serial number	Variables (N = 87)	Mean	SD	Range
1	Weight (Kg)	67.91	9.735	46.2–92.4
2	Age (years)	37.97	9.318	22–56
3	Height (m)	1.695	0.0624	1.536–1.833
4	BMI (Kg/m^2)	23.62	3.150	17.52–30.76
5	Du-Bois BSA (m^2)	1.7795	0.1350	1.467–2.124

Table 4 Descriptive statistics results for BSA expressions(in M^2)

(N = 87)	Mean	SD	Range
Du-Bois	1.7795	0.13502	1.47–2.12
Mosteller	1.7845	0.14456	1.44–2.15
Haycock	1.7902	0.15071	1.43–2.17
Gehan_George	1.7968	0.14631	1.45–2.17
Boyd	1.7986	0.15034	1.44–2.17
BMI	23.6222	3.150	17.52–30.76

Table 5 Descriptive statistics results for BMR expressions (in Kcal/day)

Serial number	BMR expression	Mean	SD	Range
1	BMR_1919	1528.08	123.389	1265.99–1706.60
2	BMR_1984	1534.03	115.73	1293.68–1704.43
3	BMR_1990	1504.08	98.61	1294.38–1640.63

Table 6 Correlations analysis among evaluated BSA expressions

($N = 87$)	Du-Bois	Mosteller	Haycock	Gehan	Boyd	BMI
Du-Bois	1	0.993*	0.986*	0.988*	0.978*	0.641*
Mosteller	0.993*	1	0.999*	0.999*	0.996*	0.727*
Haycock	0.986*	0.999*	1	1.000*	0.999*	0.761*
Gehan	0.988*	0.999*	1.000*	1	0.998*	0.750*
Boyd	0.978*	0.996*	0.999*	0.998*	1	0.785*
BMI	0.641*	0.727*	0.761*	0.750*	0.785*	1

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

Table 7 Correlations analysis among BMR expressions

	BMR_1919	BMR_1984	BMR_1990
BMR_1919	1	0.998*	0.990*
BMR_1984	0.998*	1	0.988*
BMR_1990	0.990*	0.988*	1

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

($r = 0.785$) with the Boyd expression as compared with other BSA expressions. The correlation analysis among various evaluated BMR expressions yielded a better relationship for the widely used Harris-Benedict BMR expression with the revised BMR expressions (i.e. BMR-1984 ($r = 0.998$); BMR-1990 ($r = 0.990$); at 0.01 significance level).

The scatterplots and regression line indicating the relationship between Du-Bois and different BSA (in m^2) estimates and relationship between different BMR (in Kcal/day) estimates have been shown in Figs. 3 and 4, respectively. The coefficient of determination (R^2) value showed a strong goodness of fit between the Du-Bois and Mosteller estimates ($R^2 = 0.986$). Similarly, strong goodness of fit was observed between the Harris-Benedict and revised BMR expression ($R^2 = 0.996$). The respective BSA and BMR estimates were utilized in evaluating the metabolic heat generated during different physical work activities (based on the metabolic rate for specific foundry work activities, according to ISO 8996 standard) and also the energy expenditure requirements (based on moderate physical activity level equal to 1.76) (United Nations University, World Health Organization 2004) for the targeted audience, which may be considered beneficial for conducting thermal stress evaluations in that particular high-heat work environment. Table 8 depicts the calculated metabolic heat (in watts) for different work profiles based on the evaluated BSA estimates, whereas Table 9 shows the energy expenditure requirements (at moderate level activity) for different BMR expressions. From the results, it may be concluded that the highest metabolic heat was observed for the hand molding and foundry man work profiles (upper limit (UL) varying between 427.08 and 431.66 W) followed by blast furnace work (upper limit (UL) = 391.49 to 395.69 W) based on Du-Bois expression. However, Boyd BSA expression yielded the highest metabolic heat

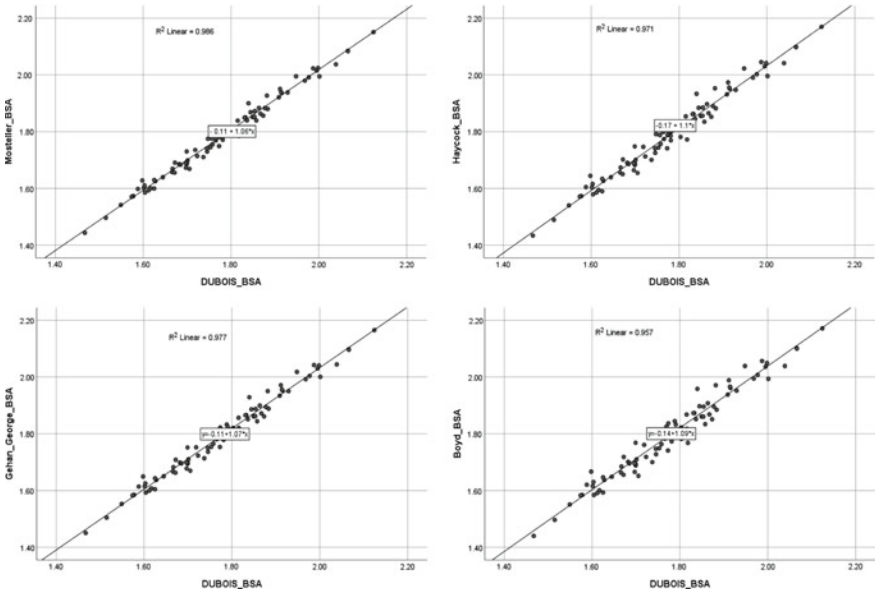

Fig. 3 Scatterplot indicating the relationship between Du-Bois and different BSA (in m^2) estimates

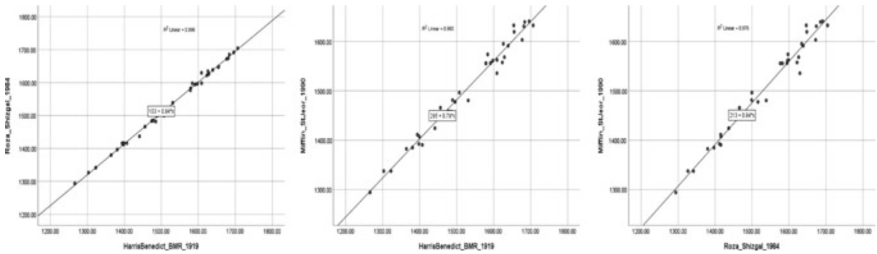

Fig. 4 Scatterplot indicating the relationship between different BMR (in Kcal/day) estimates

values among all work profiles. Similarly, based on the BMR expressions, the average daily energy expenditure requirements to maintain healthy body weight were found varying between 2647.18 kcal and 2699.89 kcal for moderate-level physical activity (Table 9).

4 Conclusions

The current study intended to perform a comparative analysis for four different BSA estimates with the widely used Du-Bois BSA estimate and also evaluating the daily energy expenditure requirements based on the basal metabolic rate (BMR) among

Table 8 Calculated metabolic heat (in watts) based on different BSA estimates

Metabolic heat (in watts) based on BSA estimates →		Du-Bois	Mosteller	Haycock	Gehan_George	Boyd
Work profile↓						
Blast furnace worker (170–220 W/m^2)	LL	302.52	303.36	304.34	305.46	305.76
	UL	391.49	392.59	393.85	395.31	395.69
Electric furnace worker (125–145 W/m^2)	LL	222.44	223.06	223.77	224.60	224.82
	UL	258.03	258.75	259.58	260.54	260.79
Hand molding worker (140–240 W/m^2)	LL	249.13	249.83	250.63	251.56	251.80
	UL	427.08	428.28	429.65	431.24	431.66
Machine moulder worker (105–165 W/m^2)	LL	186.85	187.37	187.97	188.66	188.85
	UL	293.62	294.44	295.39	296.48	296.77
Foundry man (140–240 W/m^2)	LL	249.13	249.83	250.63	251.56	251.80
	UL	427.08	428.28	429.65	431.24	431.66

LL: Lower limit, UL: Upper limit

Table 9 Energy expenditure requirements (moderate level activity) for BMR expressions (in Kcal)

Serial number	Energy expenditure at different BMR	Mean	SD	Range
1	Energy_Expenditure_1919	2689.42	217.16	2228.14–3003.63
2	Energy_Expenditure_1984	2699.89	203.69	2276.87–2999.80
3	Energy_Expenditure_1990	2647.18	173.56	2278.10–2887.50

workers employed in small-scale foundries. From the results, it was concluded that there was a strong association between the Du-Bois and Mosteller BSA estimates (correlation coefficient (r) = 0.993, at 0.01 significance level). Although the BMI index showed a better association ($r = 0.785$) with the Boyd expression as compared to other BSA expressions. From the results, it was observed that there was a strong association between the various BSA estimates (at significance level of 0.01). The highest metabolic heat was observed for the hand molding work profile (upper limit (UL) varying between 427.08 and 431.66 W) followed by blast furnace work (upper limit (UL) = 391.49 and 395.69 W) based on the Du-Bois BSA expression, whereas Boyd BSA expression yielded the highest metabolic heat values as compared to other BSA expressions. Similarly, based on the BMR expressions, the average daily energy expenditure requirements to maintain healthy body weight were found varying between 2647.18 and 2699.89 kcal. These BSA and BMR estimates may provide a better indication of the metabolic heat generated and daily energy requirements for workers involved in high work-load activities, particularly high heat work environments. These estimates may be helpful in; conducting in-depth thermal stress analysis for high-heat work environments, CFD-based thermal comfort studies for an industrial work environment and so on, which, in turn, yields better evaluation of particular thermal environment suitability for the targeted audience.

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Chapter 6
Analysis of Ergonomic Issues Faced by Students and Teachers in Online Education

K. Nirmal, K. Adalarasu, and T. Aravind Krishna

1 Introduction

Education is the acquisition of knowledge and skill. Online education (often referred to as "e-learning") is a type of learning that takes place over the internet and not in a traditional classroom setting. Until recent COVID situations, online education was limited to some correspondence courses, telecourses, CD-ROM courses, Internet-based courses offered synchronously and/or asynchronously, mobile learning using devices such as cellular phones, PDAs, and digital audio players (MP3 players, iPods, etc.). Now in COVID times, online learning has taken center stage in teaching where many educational institutions have started to take classes remotely to prevent students commuting and coming in contact with each other and hence to restrain COVID from spreading fast. Hence, students and teachers are forced to use computer-based tools such as desktop PC/laptop/smartphone and other accessories for delivering lectures, submitting assignments, and evaluation purposes. In this context, studying ergonomic issues among teachers and students due to this 'sudden' change in the educational process (as compared with a 'predominantly' Chalk and Talk method with both the teacher and the taught being physically present in the same location) becomes important and necessary for improving the quality of education at the same time ensuring health and safety of students and teachers during learning.

Ergonomics is concerned with how human performance can be enhanced by improving the design of a system and the performance environment (Forde et al.

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2002; Wells et al. 1997), Ergonomics is concerned with online education to see how interactions with the online system influence the performances of students, faculty, administrators, and staff, and how the technology can be improved to benefit student learning and the new mode of educational system.

A survey of the literature related to human factors in education shows review/work related to behavioral aspects and ergonomics. Several studies (Erick and Smith 2011; Yue et al. 2012; Chan et al. 2010; Chong and Chan 2010) have systematically reviewed MSD prevalence among school teachers. In a conventional classroom setting, a teacher's work includes preparing lessons, teaching students, writing on a blackboard, assignment grading, and administration-related work (admissions, etc.), which can lead to severe physical and mental health concerns (Chan et al. 2010; Chong and Chan 2010). In addition to the above, age, sex, length of employment, and awkward postures are also associated with a high prevalence of WMSDs. The prevalence of self-reported MSDs among school teachers has been reported to be in the range of 39–95%. Back, neck, and upper limbs are reported to be the most prevalent regions of WMSD symptoms.

A survey of the literature related to human factors in online education shows literature, which has studied specifically on behavioral aspects of online (web-based) learning. Shu Yu and Kuei-Feng Yang (2006) studied the attitudes toward web-based education as a way of in-service training among Public Health Nurses (PHNs) in Taiwan. They concluded that most trainees revealed a positive attitude toward web-based learning and that negative attitudes lead to low participation and low learning. A survey of ergonomic studies in education provides evidence that ergonomic factors such as the physical environment (Earthman 2004), environmental conditions, psychosocial factors (Zandvliet and Fraser 2005), and the organization of the course (Ginns and Ellis 2007) have a significant impact on student learning outcomes, well-being, and satisfaction.

Studies such as Smith (2007) suggest that student learning performance is influenced by ergonomics of learning and that applying ergonomic principles and practices will lead to improved performance and learning. However, currently little is known about how the various factors individually or in combination impact the student's online learning experience.

MHRD (Pragyata Guidelines for Digital Education 2020) has published a detailed document with guidelines developed from the perspective of learners. The document focuses on digital education/online for students who are at present learning from home due to the COVID-19 lockdown. These guidelines have been prepared considering ergonomics (mental and physical well-being) in addition to other relevant aspects such as Cyber safety, etc., serve as a concise roadmap for continuing with online education and enhancing the quality of education. These guidelines can be used by all stakeholders (students, teachers, school heads, parents, etc.)

In a comprehensive literature review, (Soroka 2015) also identified a dearth of studies on how ergonomic factors affect students' learning in an online learning environment. This work is one such work that seeks to address the gap and aims to study the ergonomic issues or aspects associated with online education among students/teachers. This can help plan for proper interventions such as a proper setup, devices and timetable with 'breaks to maintain health and safety.

There are many possible ways of identifying exposures ranging from self-assessment of physical exposure to measurement of muscle activations and estimated spinal loads (Forde et al. 2002; Wells et al. 1997). This paper focuses on the assessment of occupational stress-related risk factors among the students and teachers engaged in online education through pain/discomfort experienced using self-assessment Questionnaire and 36 Health Survey (SF-36) Questionnaire.

2 Methods and Materials

2.1 Participants

75 participants (30 males, 45 females, mean age (years) = 46.8; SD = 6.0 participated in this study. The participants had the following physical characteristics. Age: 35–57 years, Weight: 45–64 Kgs. All participants were students or teachers involved in online education for doing their course, currently studying engineering/arts (68 participants were students and 7 participants were teachers).

2.2 Experimental Design and Protocols

Questionnaire (google link) was E-mailed to the participants with a brief description about the study. Convenient sampling method was adopted by circulating the questionnaire among our friends and relatives working in schools and colleges (engineering and arts) in different parts of Tamil Nadu. The responses received so far were analyzed for this paper. The self-administered questionnaire collected details such as personal information (such as age, height, weight, etc.), education-related details (such as degree, subjects learnt, hours spent in online education, etc.) and health-related details (physical and mental health aspects, pain in different body parts, etc.) in addition to asking them to quantify the overall perceived pain/discomfort score at various body locations (shoulder, hand/wrist, neck, elbow, back, thigh, knee, leg and feet/ankle) (Fig. 1).

Criteria for the Pain scale and their grades are depicted in Table 1.

3 Results and Discussion

Some reports, such as (Oppenheimer 1997), question the use of computers in education and argue that the use of computers hampers learning and education system

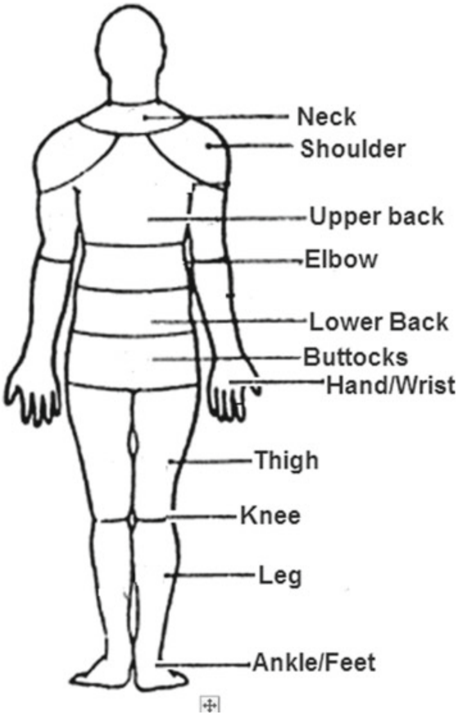

Fig. 1 Work-related discomfort/pain perceived in different parts of the body

Table 1 Pain-score criteria and their grades

Criteria for pain score	Grade
No pain, perfectly feeling well	1
Minor pain, feeling discomfort	2
Noticeable pain BUT tolerable	3
Strong pain and distressing	4
Very intense pain	5

performance in both online and traditional classroom settings. But, with technology-enhanced learning, nowadays, the use of computers and digital instruments in education (as in any other application) has become inevitable, more so in online education in pandemic situations. Here, we have studied the perception of discomfort/pain, which is a qualitative measure and is purely subjective. Questionnaires are extensively and widely used to evaluate ergonomic issues in shop floor settings. Here, we have used the same to evaluate ergonomic issues in online education.

Based on the preliminary analysis made, we report the following results, which were found to be significant.

The results of our study (Fig. 2) show that the nature of device (laptop/desktop/smartphone, etc.) used by students' had a significant effect on health

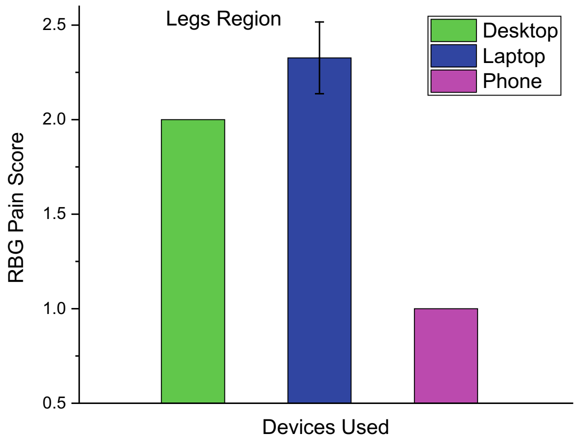

Fig. 2 Comparison of perceived discomfort/pain scores in leg region among desktop versus laptop versus smartphone users

issues. Laptop users had significantly ($p < 0.05$) higher pain in the legs when compared with desktop and smartphone users. This may be due to laptop users attending classes with laptops on their laps or not using proper ergonomics postures during online learning, which leads to high pain in legs. Smartphone users had minimal pain.

Results in Fig. 3 show that the gender of users (male/female) had a significant effect on health issues. Females have significantly ($p < 0.05$) higher pain in the neck and shoulder region compared with males. The reason we think is due to female students resorting to a particular posture for long durations in their pursuit to concentrate hard. The actual reason needs to be identified and needs further detailed investigations.

From Fig. 4, we also find that duration of online engagement has a significant effect

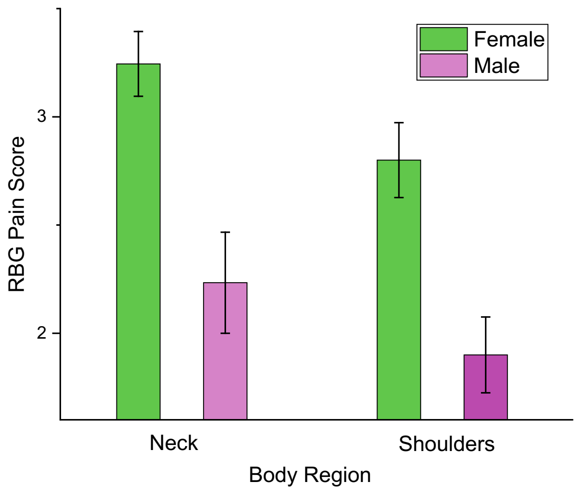

Fig. 3 Comparison of perceived discomfort/pain based on Pain score levels in neck and shoulder for male versus female

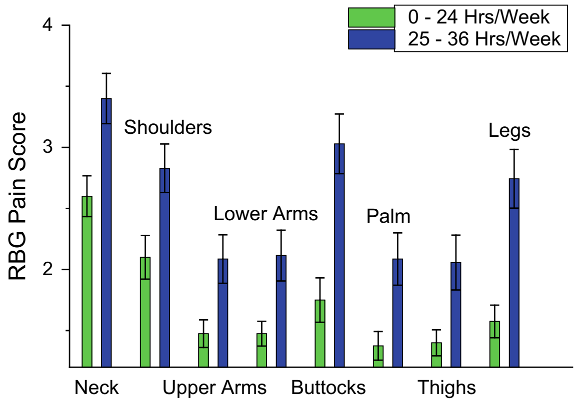

Fig. 4 Comparison of perceived discomfort/pain based on Pain score levels in various body regions for hours spent in online education (less than 24 h' vs. 25–36 h)

on health issues. On comparing the effect of durations for online learning, college students engaging in online classes for more than 24 h per week have significantly ($p < 0.05$) higher pain in most of the body regions; viz. neck, shoulder, upper arms, lower arms, buttocks, palm, thighs, and legs. The Ministry of Human Resources Development (MHRD), Government of India, has provided a guideline that the duration of online classes should not be greater than 3 h per day for students undergoing higher classes (Class 8–Class 12). Here, we are considering college students so we have considered 4 h per day; i.e., total of 24 h per week. Our result corroborates MHRD guidelines (Pragyata Guidelines for Digital Education) by showing that students engaging in online classes for more than 24 h per week are prone to severe pain and related MSDs.

The study reveals that there are ergonomic issues associated with online education and students/teachers need to consider these aspects. While engaging in online education, both the students and teachers make use of the same set of devices and are exposed to the same duration, hence both are exposed to the same ergonomic issues. Further to this, we received lesser responses from teachers compared with students (Only 9% of respondents were teachers); hence we combined the observations for students and teachers. Also, to address MSDs, we are in the process of identifying the contributing factors and providing ergonomic interventions and plans for proper interventions such as proper setup, devices, and an ergonomically designed timetable with breaks to maintain health and safety of students and teachers. These interventions will improve the health, student/teacher comfort levels and will help enhance the productivity of the teacher and the learner.

4 Conclusions

The extensive use of online education as a mode of offering education due to enabling technologies and the present COVID-19 situation has created an interest in applying ergonomic principles to study and understand online learning environments and interfaces toward enhancing the health and safety aspects of learning.

In this study, it was found that students and teachers were severely affected in the lower back and shoulder regions. This could be attributed to devices used, postures adopted, and duration (hours) of learning. The results suggest that, in the light of promoting sustainable well-being of students and teachers in online education, ergonomics need to be considered in course design. The concerned authorities (students, teachers, parents, education department/institutions) need to have a comprehensive ergonomic plan, the net effect of which can help the prevention of health risks among users of online educations and provide a safe and productive learning experience.

Scope for further research: From an application perspective, the present need is to design and target ergonomic interventions for tackling ergonomic issues toward addressing health issues and enhancing learning performance. From a system perspective, the present challenge and mission of educational ergonomics are to plan and integrate ergonomic interventions into educational system designs that facilitate stress-free learning for students of all ages.

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Chapter 7
Analysis of Musculoskeletal Disorder (MSD) Risk Factors Among Washing Machine Users in South Region of India

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1 Introduction

Washing may be a physical task, which is completed almost everywhere around the world. From the first decades to today, laundry was and still is completed manually. It's seen as physically demanding and time-consuming work. Occasionally, the entire family is involved in managing the laundry. Counting on people's income, washing was and still is usually handed over to launderers or laundresses. Many stories also as paintings underline the intensity of this work. Manual washing may be a physically demanding task in terms of awkward body postures (Balasubramanian et al. 2008; Ejiko et al. 2020), repetitive movements and high energetic workload, due to the physical agitation and wringing to urge the laundry clean. Moreover, the detergents together with high water temperatures also can be hazardous (Huang et al. 2018).

In the recent few decades, the utilization of laundry machines for easy laundry rather than hand-washing has become quite common among several households. It's a blessing for the operating population, elderly (Huang et al. 2018), and maids because it significantly reduces the physical strain and time related to manual laundry. At the time laundry machines were fictional, most of them were supported the principle of a tub. Then on the previous principles of

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a tub, high loaders rotating around vertical axis become widespread. Subsequently, laundry machines were designed as front loaders, rotating around a vertical axis.

Though washing machine designs have evolved over years toward reducing physical effort, there are still a few basic tasks such as loading and unloading clothes, operating controls, and panels, which are strenuous during operation and prone to health issues in the long run. Washing is also an activity, which is very hard to perform for elderly people (Barrett and Kirk 2000). The development of musculoskeletal disorders (MSDs) is the common problem among washing machine users. Ergonomic study and recommendations help to address such issues and ensure the well-being and safety of the users (Balasubramanian et al. 2008). Ergonomic assessment is an essential part of ergonomic assessments and interventions. It helps in targeting improvements toward enhancing quality of life (Baumgartner et al. 1998; Balasubramanian et al. 2014).

Ishihara et al. (2008) studied the postures assumed by washing machine users using three-dimensional motion capture devices. The working postures measured were analyzed using human kinematic models (3D SSPP). The model was used to estimate theoretical values of muscle tension and loads on the lumber vertebrae, knees, and ankles. The study recommends a new washing machine design, which will need only 40% of the muscular force required as compared with conventional washing machines.

Keiko et al. (2015) used Kansei ergonomics (tool for product development) for studying the posture of users while using washing machine. Measurement of working posture showed that slanted drum design was superior compared with the horizontal drum or conventional vertical designs. Ergonomic Function Deployment (EFD) was used to improve the design of the product according to the ECSHE principle (Effective, Comfortable, Safe, Healthy and Efficient) (Fakhriza et al. 2017; Beniuk et al. 2011). The results of this study used the concept of ergonomic products based on product attributes referring to the principle of ENASE (Effective, Safe, Healthy, Comfortable, and Efficient). Rapid Entire Body Assessment (REBA) to evaluate the body postures while using clothes dryer and obtained Motion data using three-dimensional motion analysis system (Kim and Bae 2018). Results showed that the risk of loading and unloading clothes for side swing opening door exceeds the medium level of risk. Analysis of three-dimensional motion and virtual human model showed significant changes in the subjects'. Design changes such as clothe dryer paired with a top load washing machine modified to open up and close down by 30 degree etc. were suggested.

Blain-Moraes et al. (2012) designed and fabricated a manual washing machine to prevent contact between tap and hand. The machine employs the use of pedal operated clutch cable and a return spring to operate the water tap, while making use of pedal operated contact spring for the spraying of soap. The average human height was considered to make the machine ergonomically satisfactory, so as to make its usage more comfortable. Thus, ergonomic evaluation of manual operations among individuals using washing machine has been in vogue for more than a century (Blain-Moraes et al. 2012). The evaluation was based on the design of panel, height of the washing machine, etc. Discomfort or pain perceived on various regions of the human body for individuals is yet to be researched. Thus, to overcome limitation in which the pain scale hasn't been analyzed, this study aims to analyze the ergonomic issues associated with washing machine users in south Indian population through RBG (Rehabilitation Bioengineering Group) Pain scale. This study also aims for innovative washing machines in terms of good usability, design, and comfort.

2 Methods and Materials

2.1 Subject Summary

An Ergonomics survey with the aid of a self-assessment questionnaire was conducted among 149 subjects (98 females and 51 males) in the age group of 16–80 years (the average age was 56 years). The average height of the users was found to be 95 cm while the average weight was 70 kg. The average hours spent using washing machine was 24 h per week. The survey was circulated among our friends and relatives using Google Forms.

2.2 Methods

A questionnaire was developed to explore the ergonomic issues associated with products with the following topics:

(1) Ergonomics of washing machine usage
(2) Inconveniences and difficulties faced by washing machine users.

Display design, panel design (Fig. 1), top, front-load designs (Bao et al. 2017) were investigated for musculoskeletal disorders (MSD) using the RBG (Rehabilitation Bioengineering Group) Pain score as shown in Fig. 2. RBG Pain score was analyzed in body, neck and shoulder, upper arm, low back, and knees regions.

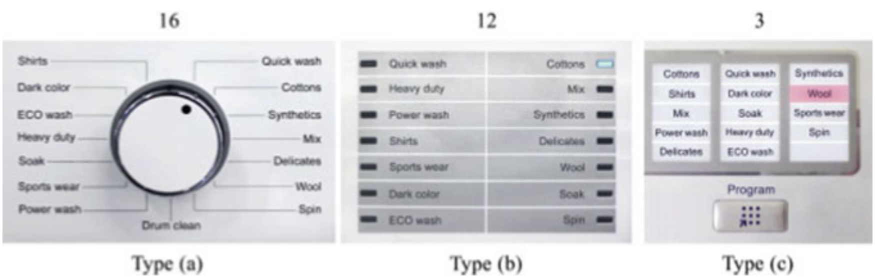


Fig. 1 Common types of panel design used in washing machine (Huang et al. 2018)

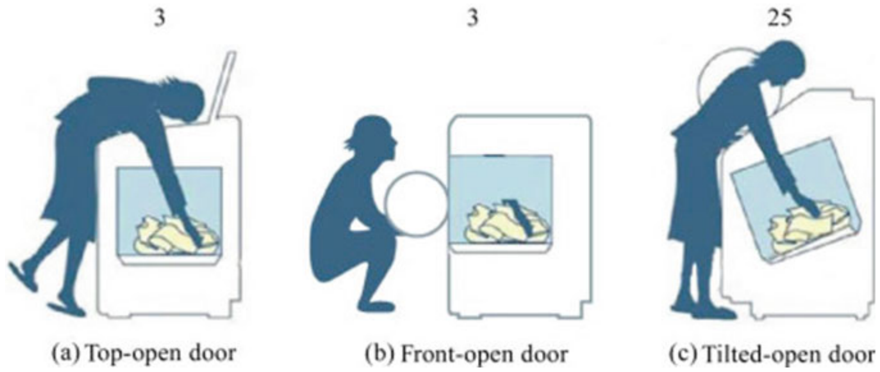


Fig. 2 Common types of washing machine doors (Huang et al. 2018)

During the survey, the participants were allowed to discuss related to the topics and express their opinions. This was very much helpful for the researchers to get a deeper understanding of users' ideas/issues faced.

A self-administered questionnaire was provided to check the overall discomfort score while using washing machine at body regions, neck, shoulder, upper arm, low back, and knee (Fig. 3).

Fig. 3 Typical regions of the body where the discomfort is experienced

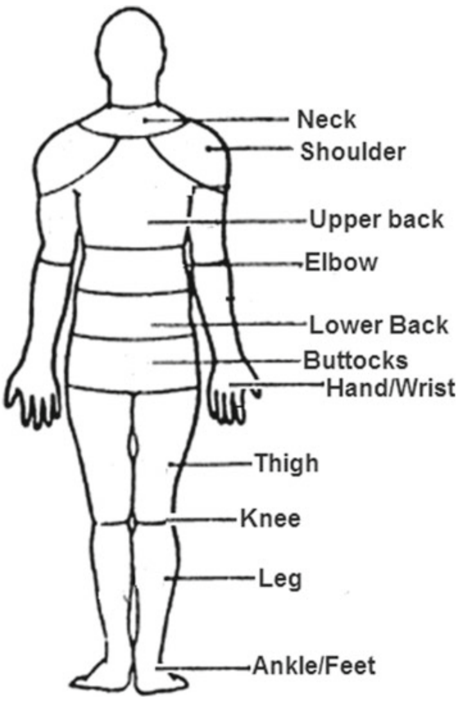


Table 1 Criteria for pain scale and score

Criteria	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

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 are 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 reliability of the collected data. Reliability of the data is found to be 0.70. Thus, the collected data fall under good reliability score. Criteria for Pain scale and their score are depicted in Table 1.

Workers performing washing tasks using different types of washing machine design (Figs. 4 and 5) such as top open door, front open door, and titled open door machines were assessed.

Huang et al. (2018) concluded that people are much comfortable with tilted open loading machines. But, we have not considered tilting machines in our study (not

Fig. 4 Subject working with front-load washing

Fig. 5 Subject working with top open washing machine

much commonly used in India). Using our study, we find that the use of front open washing machine produces less pain when compared to top open machine. Figure 6 shows the mean value of RBG Pain score obtained from the Ergonomics survey of washing machine. Statistical results show that subjects who use top-loading washing

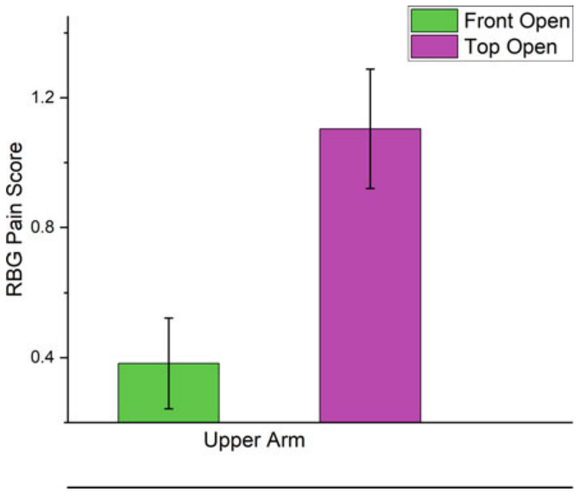
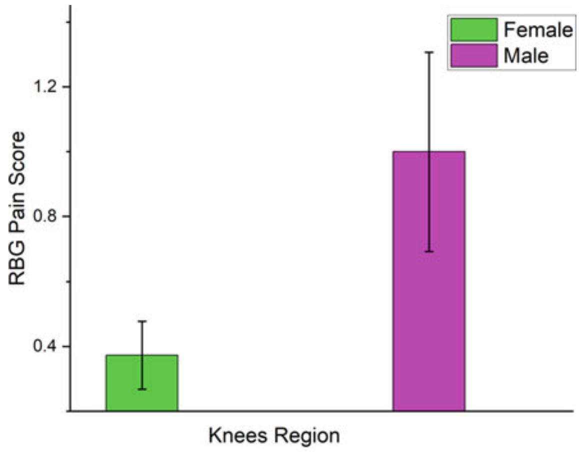


Fig. 6 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of various types of loading design for upper arm region

Fig. 7 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of gender (male vs) for knee region



machine have significantly ($p < 0.05$) high pain in the upper arm compared with those using front-loading washing machines as shown. While loading clothes in top open machine, people feel very high pain in the upper arm compared with those loading clothes in front open machine. In top loading machine, people have to stretch their hands while loading clothes, this may also cause pain in their upper arm.

Statistical result shows that male subjects have significantly ($p < 0.05$) high pain in the knee region compared with female subjects (as shown in Fig. 7). While using washing machine and loading clothes, male subjects have high pain in their knee region than female subjects. This may be due to the multitasking ability of the females, which makes them experience very less pain during the washing activity compared with males.

Huang et al. (2018) identified that people feel comfortable with simplified and normal panel designed machines with less number of buttons. However, in the present study, we find that panel with full button type of washing machine produce less pain. Figure 8 shows that among the different panel designs, people who use washing machine with knob design have significantly ($p < 0.05$) high pain in body, neck, and shoulder regions as compared with panel design with jumping lights and panel with full buttons washing machine. People who use knob design washing machine have to strain more than the other types of washing machines. Similarly, people who use washing machines with jumping lights feel light pain in their body and knee regions. This is because people have to give more force to press the jumping lights buttons. Thus, washing machine with full button panel is comfortable to use as it causes less pain compared with the other two types of panel.

The BG Pain score was significantly ($p < 0.05$) high in body region and upper arm for touch screen type button design when compared with plastic and rubber designs as shown in Fig. 9. Those who use touch screen types of buttons experience more pain in both body and upper arm regions. This is because in touch screen types, people have to give more force on their finger, which causes more pain in body and upper

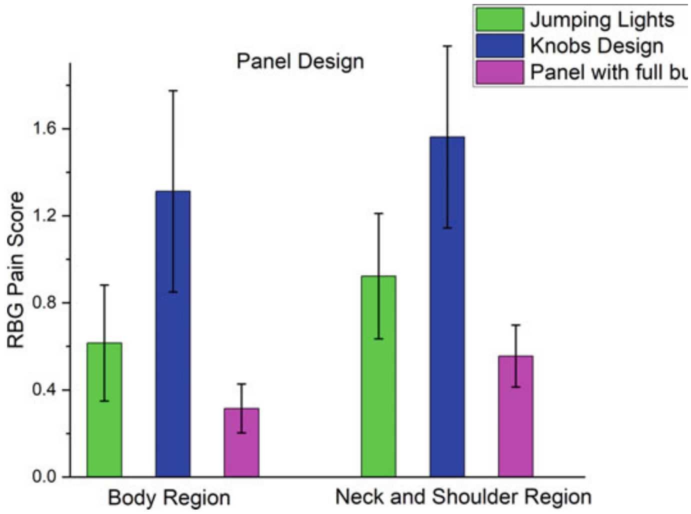
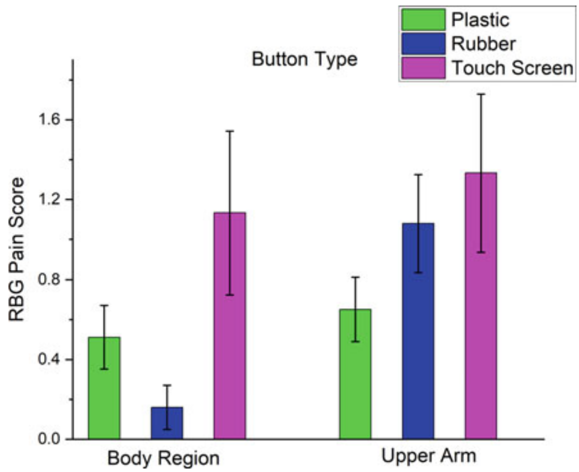


Fig. 8 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of various types of panel design

Fig. 9 The mean and one standard error value of RBG (Rehabilitation Bioengineering Group) Pain score of various types of button designs



arm regions, more so when water droplets fall on the touch screen as it requires more force than usual force in addition to slipping effect of fingers. On comparing plastic and rubber type buttons, plastic button causes little pain in body region compared with rubber button and similarly rubber button experiences high pain in upper arm region compared to plastic buttons. Thus, from the survey, it is clear that plastic buttons and rubber button experience less pain compared with touch screen.

3 Conclusion

The main aim of this research work was to find the ergonomic issues associated with washing machine users in South Indian Region. Our study result provides clear evidence that the use of washing machines leads to MSD disorders. This study also explores the people's preferences, demands, and suggestions for washing machines. Since washing machines are one among the most commonly used household appliances, the results of this study can also contribute to further improve the design of many other such household appliances. This study also reveals that the ability of females to perform multiple tasks makes them experience less pain when using washing machine. Based on the findings of the study, it is recommended that front loading with rubber button design is an appropriate ergonomics design for washing machines. It is important for engineering designers (product designers and engineers in the household appliances industry) to consider functional capabilities and limitations of users (all genders and all age groups) when designing products for daily use and daily living environments.

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Chapter 8
Analysis of Working Postures in a Small-Scale Fastener Industry by Rapid Upper Limb Assessment (RULA) Using CATIA Software

Nikhilkumar, S. M. Qutubuddin, R. P. Pallavi, Avinash Sambrani, and Deepika Padashetty

1 Introduction

Workers in industries normally report discomfort in work, leading to the development of musculoskeletal disorders (MSDs) over a period of time, and these are the most prevalent issues in the informal sector (Manzoor Hussain et al. 2019). The work in SSIs is usually manual, basically comprises of repetitive activities involving awkward postures, frequent twisting, stretching, bending, vibrations and contact stresses (Qutubuddin et al. 2013). Several tasks also involve manual material handling, which includes lifting or lowering of loads, pushing or pulling, carrying or moving heavy loads with different kinds of postures (Deros et al. 2010; Boulila et al. 2018; Binoosh et al. 2017; Singh 2010; Kamat et al. 2017; Yadi and Meily Kurniawidjaja 2018). These are some of the signs of developing musculoskeletal disorders over a period of time and may lead to reduced work capacity and perhaps loss of function (Jagadish et al. 2018), if not corrected initially.

It is necessary for both the employers and operators/workers to promote the use of ergonomics in industry. One important step toward this is awareness, education and training. In most of the ergonomic intervention studies, it is observed that workers are unaware of the benefits of applying ergonomics, and thus become prone to various risks (Boulila et al. 2018; Binoosh et al. 2017). Over the decades, ergonomic studies and interventions have been instrumental in increasing overall effectiveness and reducing musculoskeletal disorder risk factors in various occupational settings, especially in small and medium industries (Singh 2010; Jagadish et al. 2018). However, it has been observed through literature that ergonomic studies and postural improvement to reduce risks in fastener industry are very limited. Therefore, the main objective of the study is to find the postural risks in fastener industry to reduce the risk of musculoskeletal disorders and workstation design issues.

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1.1 Postural Analysis

Several studies can be found in the literature on postural analysis by ergonomic assessment methods like RULA, REBA etc. The main purpose of such studies is to eliminate or reduce the musculoskeletal disorder risks and to find any mismatch between the worker and workstation design. Some examples of such studies using RULA are on bus body building industry (Qutubuddin et al. 2013), automotive manufacturing (Deros et al. 2010), mechanical manufacturing industry in Tunisia (Boulila et al. 2018) and in a pump manufacturing industry (Binoosh et al. 2017). Singh (2010) carried out a similar study on forging industry. It can be drawn from various studies that there exists a relationship between the formation of musculoskeletal disorders and awkward postures. The different assessment tools are used by researchers to identify the risky postures, the quantum of risks and recommend suitable measures for reducing the risks.

1.2 Digital Human Modeling as Ergonomic Assessment Tool

Virtual Ergonomics and DHM has rapidly emerged as significant technology in product design, workplace or workstation design among many of its applications (Manzoor Hussain et al. 2019). Many ergonomic evaluation methods are incorporated in software such as 3DSSPP, JACK, CATIA etc. DHM and simulation tools are considered to facilitate proactive ergonomics investigation. The uses of DHM technologies allow the researcher/ergonomist for early identification of ergonomic issues, and thereby reduce/eliminate the need for physical and real human worker testing.

DHM technique gives a 3D visualization of operator doing various tasks/activities and provides guidelines to analyze and design workstation ergonomically (Manzoor Hussain et al. 2019). The functions of DHM are many, such as analysis of posture, push–pull analysis, load analysis, and movement of human manikin in predefined motion, RULA assessment and building the manikin as per anthropometry data. Several studies can be found in literature on the use of DHM and simulation in ergonomic assessments such as (Binoosh et al. 2017) in pump manufacturing, (Kamat et al. 2017) in warehouse of aerospace industry and (Manzoor Hussain et al. 2019) in stone cutting and polishing units. Yadi et al. (2018) conducted a study on chemical industry workers and analyzed the postures using CATIA.

2 Methodology

2.1 Rapid Upper Limb Assessment

McAtamney and Corlett (1993) have developed the RULA method for upper limb risk assessment. It is a simple tool for rapid assessment of the upper limb, trunk and neck. It generates an action level list with a code indicating intervention necessary to reduce the risks of unnatural postures. It provides final posture score, movement and force required. The score are grouped into four levels, of action categories that give an indication when a risk control action should be initiated.

RULA assessment tools consist of two parts A and B. In part A, the upper arm, wrist, lower arm and wrist twist are assessed. The operator's posture is assessed through the photos taken by marking the angles and using a goniometer to measure the angles the different body parts make. Against the observations, the corresponding scores are noted down from the RULA score sheet. This gives the total part A score. In part B, the legs, trunk and neck scores are obtained in similar way. This gives total part B score. These scores are added to the score for any muscle use and force. Corresponding to the scores from A and B, from table C in RULA score sheet, the final score can be obtained. This is the score that determines the risk category and action level. The following Table 1 gives the details of RULA action level, the risk category and a description of action to be taken.

2.2 Preliminary Study

An initial observation and survey of the workplace and work environment are carried out to understand the nature of problems and issues related to the development of work-related musculoskeletal disorders and discomfort among the workers due to posture. Preliminary observations included the understanding of the work methods, compatibility between the work systems and worker anthropometry, getting feedback about pain/discomfort due to unnatural postures and the overall work environment. The study consists of three stages approach; selection of workplace through direct observation and discussions, taking photographs and video of working postures for

Table 1 RULA action level, score and brief description

Action level	Score	Summary
AL1	1 or 2	Indicates negligible risk. Posture is acceptable
AL2	3 or 4	Indicates low risk. Further investigation and change
AL3	5 or 6	Indicates medium risk. Further investigation and change soon
AL4	7	Indicates high risk. Further investigation and change immediate

postural analysis and DHM using CATIA software for risk analysis and ergonomic interventions.

2.3 Digital Human Modeling Using CATIA

In the current work, CATIA is used for RULA analysis of selected postures. For RULA analysis, photos of the posture are taken and converted into a 3D model by CATIA software. For building the human manikin in software, proper anthropometry dimensions are taken into consideration. The relevant standing and sitting body dimensions are fed into the software to build a real like manikin. Using CATIA software a virtual environment is developed. The anthropometric dimensions selected for building human manikin were 50th percentile of Indian population data (Chakrabarti 1997). The 3D human manikin built is an exact replica of the observed posture of worker. In ergonomics design and analysis of the workplace, DHM has been in use over a long time. The benefit of DHM is that it integrates dynamic simulation and ergonomics assessments enabling the designer to visualize the workplace and improve in digital/virtual environment (Boulila et al. 2018; Binoosh et al. 2017). The method for assessing the workplaces in digital environment was first suggested by Chang et al. (2007) to prevent WRMSDs. Other several benefits of DHM include (1) ergonomic assessments can be performed as early in the design process and (2) ergonomic issues/concerns and alternative designs can be communicated (Manzoor Hussain et al. 2019; Chang et al. 2007).

3 Results and Discussion

3.1 Bolt Manufacturing Process

Bolt is a piece of metal rod, whose one end is up settled and threaded at another end. The bolt-making process is a high-speed multi-blow press. First, the straight wire rod is cut into required size for bolt making. Then the MS rod is fed to cold heading machine, which is actually a high-speed multi-blow press, which makes a hexagonal head at one end. There are a series of dies in the heading machine, and the unheaded metal is forced to flow into the dies to change its shape. The machine cuts one end of the rod into required length with cutting stroke and head formation takes place simultaneously at the other end. After that, the material is sent to the trimming machine for cutting the edge of the bolt. Then the bolts are fed into a threading rolling machine for making threads. The finished bolts are polished in a polishing machine. The entire process of manufacturing bolts is shown in Fig. 1.

The round MS coil is fixed into a coil holder, the edge of the rod is ground to be fed into the forging machine. The round MS rods are passed through a set of rollers to make it perfectly straight before being fed into a cold forging machine. The high-speed cold forging machine is fully automated has one die with two strokes, which makes the head shape of the bolt. The round-headed bolts are collected manually from beneath the machine and moved to trimming machine. The next operation is threading in a thread rolling machine, where the bolt passes between two rollers. The bolts are then polished in a polishing machine and then packed for delivery to the customers.

The current work is done in a small-scale fastener industry located in Kalaburagi District. The industry employs about 22 workers, comprising of a manager, supervisor, machine operators and helpers. The industry operates in a single shift. The industry has cold forging machine, head trimming machine, threading machine, polishing machine and a facility for heat treatment. Each machine has a capacity of about 40–90 bolts per minute. The total capacity of the plant is about 400 MT per annum, and the total power required is 90HP. The finished bolts and nuts are consumed in the local and nearby markets.

The workers have explained the purpose of the study and their consent obtained orally. Several working postures were videotaped and photographed for further analysis using RULA technique. Anthropometric measurement of relevant body parts in sitting and standing positions was taken to find any mismatch between the work system design and operators discomfort. Anthropometry measurements are taken to build human manikins for modeling and analysis in CATIA (Fig. 2).

After having the discussions with the supervisor and workers, and by direct observations, some of the major areas concerning awkward postures and prevalence of MSDs were identified. The awkward postures adopted by the workers must be corrected through ergonomic assessment methods and ergonomic interventions

Fig. 1 Bolt manufacturing process

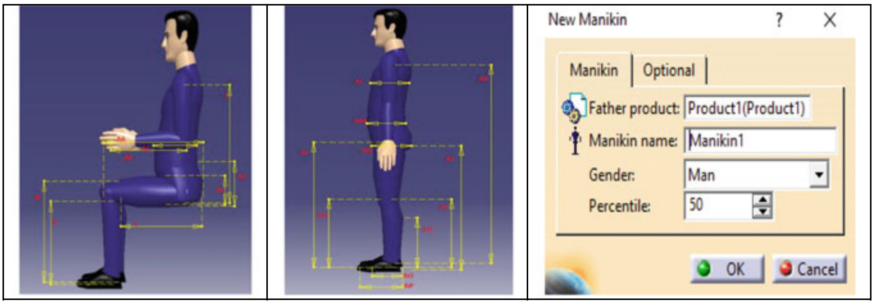

Fig. 2 Anthropometric measurements of sitting and standing posture

either through engineering controls or administrative controls. The focus of the study was the operator's postures at the cold head forging machine and trimming machine.

3.2 *Postural Issue at Cold Head Forging Machine (A)*

It is observed that one worker is continuously sitting in awkward posture near the machine to lubricate the wire rod, which is fed into the cold forging machine. The main task of the operator is to dip a piece of cloth in oil and wipe the MS rod which is fed into the machine. The frequency of the work is every 5 min for duration of about 10–15 s. In Fig. 3, the details of the build-up to the human manikin in CATIA and the range of motion of different body parts such as upper arm, neck, shoulder and eye sight are shown. Figure 4a shows the existing posture of operator recorded through photograph. The existing posture is modeled in CATIA human manikin and RULA analysis is done (Fig. 4b). The final RULA score obtained was 7, (Fig. 4c) which indicates high risk and needs immediate interventions to correct the posture.

To overcome this drawback, a stand is designed in CATIA with a lubricant container, which can be placed near the machine (Fig. 5a). The flow can be adjusted such that very small drops of lubricant fall on the wire rod, thus lubricating it. A

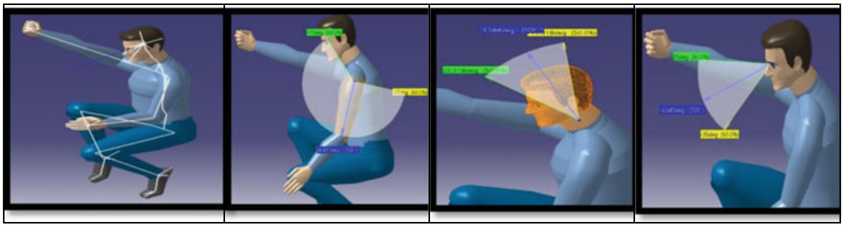

Fig. 3 Range of motion for various body parts for posture in CATIA analysis

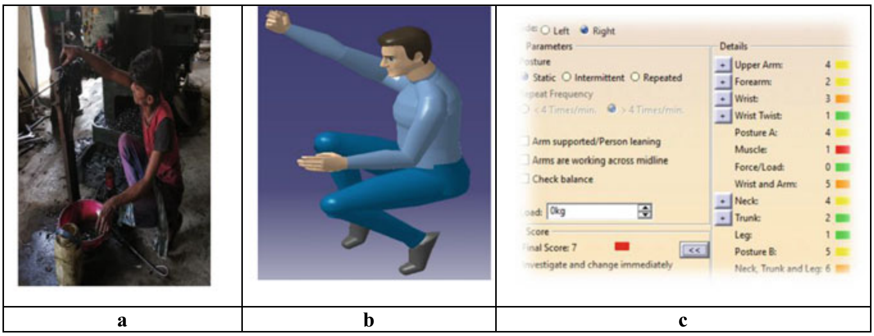

Fig. 4 Existing posture (**a**) and modeled posture (**b**) in CATIA and RULA score (**c**)

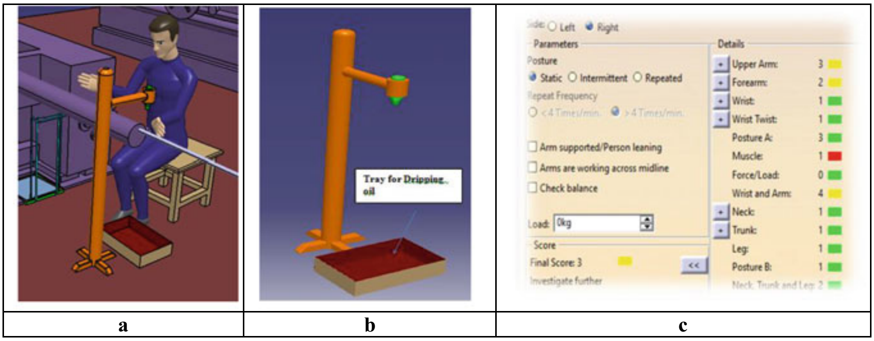

Fig. 5 Improved posture (**a**) and ergonomic intervention for lubrication (**b**) and RULA score (**c**)

small tray is placed on the floor to collect the dripping oil and avoid spillage on the floor (Fig. 5b). A sitting arrangement can be made for the worker to monitor the flow adjustments whenever necessary. The new worker posture is again analyzed in CATIA simulation using RULA assessment tool. The score obtained was 3, indicating low-risk category.

3.3 Postural Issue at Cold Head Forging Machine (B)

The main concern observed at the cold head forging machine is removing the finished bolts and rivets from beneath the machine. The machines are usually manually operated or semi-automatic, where the manual element is more, material handling is carried out manually. The movement of bolts from cold head forging machine to the trimming machine, threading machine and polishing machine is done manually. The operators use some kind of shovel to pick up the bolts from the floor and put them in a metal basket. The approximate weight of each load is about 10–12 kg. The workers lift the metal basket, carry it over a few meter distances and load it into the next machine. The work involves considerable bending, twisting, working above the shoulders and carrying loads in unnatural postures. This step is repeated frequently.

Figure 6a shows the operators present posture while performing the task of removing the finished bolts from beneath the machine. In the cold forging machine, the bolts fall to the ground and they need to be collected and moved to the next process. Depending on the size of the bolts, the work is performed frequently to remove the bolts before they get piled up. The frequency of activity is every 15 min and duration about 2–3 min. An ergonomic intervention is recommended for this activity.

After analyzing the existing posture and having discussions with the operator and supervisor, a need was felt to design a low-cost intervention, which can improve the work posture as well reduce the manual handling. A simple tray cum trolley was designed in CATIA taking appropriate measurements of available space beneath

a. Existing work of removing bolts	b. CATIA model	c. Existing tool

Fig. 6 **a** Operator removing bolts from the machine with a tool, **b** CATIA model of existing posture and **c** Existing tool used to pull the bolts from beneath the machine

the machine, as shown in Fig. 7. The tray consists of two handles and a locking mechanism to hold it stationary. It is fitted with small wheels at the bottom. The span of the tray is about 350 × 350 mm, and it can hold up to 10 kg of bolts, depending on the size. The operator can push the tray beneath the machine space available and remove it easily without bending.

The forged bolts from the machine fall directly on the tray. Proper cushioning is provided on the base of the tray to avoid the noise of falling bolts on metal tray. The operator can pull the tray once it is full so that the bolts can be removed from the tray. This activity requires very little force and the operator's posture while performing the work is acceptable. This small intervention reduces the risk to the operator's posture. RULA analysis was carried out on both the existing posture and the new improved

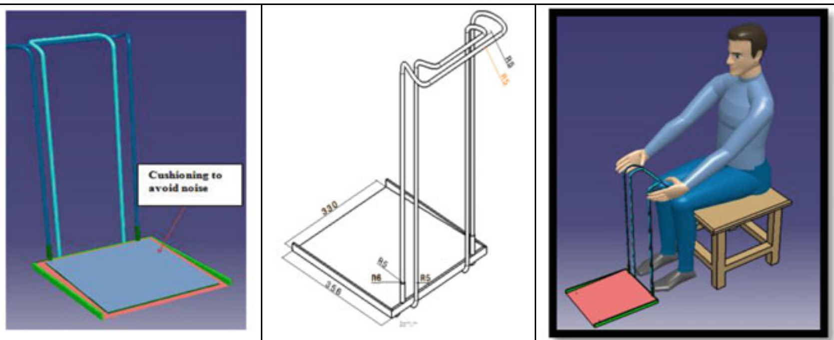

Fig. 7 Low-cost intervention for removing the bolts from beneath the machine

Table 2 Comparison of RULA assessment scores

Posture	Description of activity	RULA score	Improvement	Improved posture score
01	Operator lubricating the MS rod being fed into cold forging machine	7	A simple ergonomic intervention where a lubricant is kept on a stand (Fig. 2a)	4
02	Operator removing semi-finished bolts from the machine using a tool	7	A simple tray with handle is designed. the work simplifies the operator posture	3

posture. The existing posture showed a final score of 7, whereas the analysis on the improved posture with the ergonomic intervention has a final score of 4.

Comparison of the RULA assessment scores for the existing posture adapted by the operator and the suggested improvement score (Table 2). It is seen that small low-cost ergonomic interventions are necessary for the improvement of working postures. As shown in a study by Jagadish et al. (2018), the posture assessment result showed more than 50% of posture under high and very high-risk categories.

Similarly, some of the worst postures of the operators at the trimming and threading machines are modeled in CATIA for posture analysis. The operator has to perform activities like machine setting and adjustments intermittently. This requires the operator to adapt some awkward postures like bending at the back and neck, twisting, turning etc. Rapid Entire Body Assessment (REBA) is carried out to find out the extent of risks prevalent. All the six postures showed the (Table 3) final REBA score of 10, 11 or 12. This shows the operators' posture has a risk from high to very high signaling these postures should be changed immediately to avoid forming of MSDs. The table shows the group A score (comprising leg, trunk and neck scores) and group B scores consisting of arm and wrist scores. The final REBA scores is the summation of group A and group B scores plus the activity score.

In a similar study conducted on forging industry workers in small-scale industry, results of RULA showed about 30% of operators work in high risks due to postures adapted (Yadi and Meily 2018). Several corrective measures were suggested to

Table 3 REBA analysis scores of a few selected postures

Posture	WP1	WP2	WP3	WP4	WP5	WP6
Group A score (neck, trunk and leg)	8	9	7	8	9	8
Group B score (arm and wrist)	9	10	8	6	7	10
Final score	10	11	10	10	10	12
Risk level	High risk	Very high risk	High risk	High risk	High risk	Very high risk

improve postures and reduce the risks of MSDs. In another study by Jagadish et al. (2018) wherein RULA assessment tool was used to identify the risks in SSI workers in traditional industries like Brick industry, Pulse (dal) process industry, Saw Mill and Stone polishing industries. All the studies concluded that more than 50% of operators are prone to developing musculoskeletal disorders as a result of awkward postures. From the current study, another fact came to be known is not using safety and personnel protective equipment (PPEs). In almost every study on ergonomic evaluation or assessment of work place in SSIs, it is reported that no safety devices or protective equipment are used. The proper training and awareness about the benefits of using PPEs are recommended.

4 Conclusion

A case study of a small-scale fasteners industry (nut and bolt manufacturing) is taken up as part of the project. Several unnatural postures were identified at different machines like cold head forging machine, trimming machine and thread rolling machine. The present postures were assessed using appropriate tools like RULA and REBA. The assessments revealed a score of 7 in RULA clearly indicate high risk, meaning an investigation is required urgently and change immediately. Incorporating ergonomic considerations and engineering controls, the workstation was redesigned to eliminate the drawbacks of the present workstation. The improved posture in changed workstation was assessed again and a RULA score of '3' and '4' is obtained, meaning the posture is acceptable. Similarly, some postures were assessed by REBA and indicated high risks. If the postures are not corrected by ergonomic interventions, it may lead to the development of MSDs. Several ergonomic deficiencies were found during the study, and it was recommended to alter the workstations by having small ergonomic interventions. Such changes would definitely improve the workers' posture, increase efficacy and reduce the risks of MSD.

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Chapter 9
Assessment of Physiological Strain in Male Food Grain Cultivators While Engaged in Manual Water-Lifting Task During Paddy Cultivation Time in a Southern District of West Bengal

Ayan Chatterjee, Sandipan Chatterjee, Neepa Banerjee, and Shankarashis Mukherjee

1 Introduction

Rice is the main staple food that supplies energy as it is a rich source of carbohydrate. Cereal grain contains 60–70% of starch and is excellent energy-rich foods for humans. Cereals are an excellent source of fat-soluble vitamin E, which is an essential antioxidant. In spite of this, the cultivation of cereals grain like rice is dependent on manual effort of the agricultural workers (Chatterjee et al. 2020a, b). Food grain cultivators work manually throughout the year irrespective of disparity in the thermal working condition existing in the working environment. On the other hand, climate change phenomenon caused inter alia due to global warming, because of increased emission of greenhouse gases (GHGs) has been responsible for about 0.6 °C rise in ambient temperature during the twentieth century and at present, the rate of increase is 0.2 °C per decade. It is projected that 1.8–4.0 (average 3.0) °C increase will take place by 2100 AD depending on actions taken to limit GHG emissions and future developmental scenarios (Kjellstrom et al. 2016). Moreover, increase in rise in ambient temperature, which is taking place, in our tropical environment associated with climate change is having a profound impact on several sectors of the society including public health, especially for individuals occupationally exposed to high temperature (Mukherjee 2015). The agricultural work is most commonly seasonal, and during summer harvest, workers often spend long hours under direct sun, in

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intense heat, performing arduous physical labor. These manual tasks may be physically demanding through their energy requirements and are commonly regarded as a source of drudgery for the human resources engaged in different tasks during rice cultivation time (Chatterjee et al. 2019b). Different tasks of rice cultivation (i) selection of seeds, (ii) land preparation/plowing, (iii) uprooting the seedlings and transplantation of paddy seedlings, (iv) weeding, (v) supplying water, (vi) spraying Fertilizer, (vii) reaping or cutting rice plants and tying up the plants and carrying the plants, (viii) threshing the plant, (x) cleaning, (xi) storage of rice grain and parboiling. After the transplanting, water should be allowed to stand in the field at a depth of two to five centimeters till the seedlings are well established. Water is supplied into paddy field by the manual water lifting; it is fully controlled by the coordination of one leg and one arm of the human resources engaged. In this backdrop, the present study was undertaken to assess the physiological strain in terms of indices of physiological strain in food grain cultivators while engaged in manual water-lifting task during 'Aman' (also known as Winter paddy, cultivation period: May to December) and 'Boro' (also known as Summer paddy, cultivation period: November to March) type of paddy cultivation time.

2 Methodology

Initially before obtaining the data from the food grain cultivators, preliminary works involving the selection of the field study were carried out. After getting clearance from the institutional authorities, male individuals (age range 24–36 years) residing in and around village Selampur, Goghat II administrative Block, Arambagh Subdivision and Hooghly District, were requested to take part in the study. Food grain cultivators having a minimum working experience of 5 years and no known history of illness (self-reported) and regularly working for at least a period of six to six and half hours in the agricultural field and also willingly expressing their desire for being included in the study were only considered for random selection. On obtaining the initial consent from the study participants, the study requirements were explained elaborately. Data were collected during July to the middle of September and during the period February to April. These data were presented in two spells, i.e. morning [6.15–9 a.m.] was referred to as spell 1 [S1], similarly around noon [9.30–10.00 a.m. to about 1 p.m.] was referred to as spell 2 [S2]. It may be also mentioned that the data of individuals who were available for study during both seasons were only considered for analyses. Data were collected from 37 adult male food grain cultivators while they were taking part in manual water-lifting task during 'Aman' and 'Boro' type of paddy cultivation. These data were tabulated as the data from manual water-lifting group (WL-A) and (WL-B). Initially, name, age (year), ethnic background, average working time (hr day^{-1}), and working experience (year) of the study participants were recorded to each individual in a pre-designed schedule. Information for the assessment of socio-economic status of the participants was recorded by using Kuppuswamy's socioeconomic scale [SES] (Ravikumar et al. 2013). Stature in cm and body weight in kg were measured using stadiometer and a weighing scale, respectively. Body mass index (BMI) (kg m^{-2}) was calculated from the measured stature and body weight (BW) data. Pre-work heart rate ($HR_{Pre\text{-}work}$) of the study participants was recorded and/or by using the polar heart rate monitor and stopwatch before the individuals started their work and expressed in beats min^{-1}. Pre-work systolic and diastolic blood pressure ($SBP_{Pre\text{-}work}$ and $DBP_{Pre\text{-}work}$) also recorded during the morning hours before the individuals started their working and/or by using an automated blood pressure monitor and sphygmomanometer in sitting condition and expressed in mm Hg. Heart rate was monitored by using heart rate monitor (Polar) and data were recorded at a regular interval during the activity period of paddy cultivators in two different working spells and finally, the highest values of heart rates in each spell were presented as Peak heart rate (HR_{peak}), expressed in beats min^{-1} (Astrand and Rodhal 1986). Net cardiac cost (NCC) was obtained as the difference between working and pre-working heart rate of the study participants and was expressed in beats min^{-1} (Chamoux et al. 1985). Peak estimated energy expenditure (EEE) of tasks was obtained and was expressed in kcal min^{-1} (Ramanathan et al. 1967). The 'heaviness' of work was adjudged in terms of HR_{peak}) (beats min^{-1}), NCC) (beats min^{-1}), and EEE) (kcal min^{-1}). In case of basic environmental parameter—Dry bulb (T_{DB}) and Wet bulb (T_{WB}) temperature were measured with the help of hygrometer. The dry bulb temperature was recorded thereafter during the working hours in the agricultural field (Heidari et al. 2015). Wet bulb globe temperature (WBGT) index (°C) was found out. Corrected effective temperature (CET) (°C) was determined from T_{DB}, $T_{WB,}$ $T_{G,}$ air velocity (AV) from specified nomograms (Brake and Bates 2002). Discomfort index (DI) (°C) was determined from T_{DB}, T_{WB} values as follows (Epstein and Moran 2006). The collected data were tabulated, analyzed, and were tested for significance with analysis of variance (ANOVA), as appropriate. As the thermal environmental conditions were assessed in terms of several indices, the correlation between them was found out. *P* value lower than 0.05 ($P < 0.05$) was considered significant.

Line diagram of water-lifting task has been presented in Fig. 1.

3 Results

Basic profile of the study participants has been presented in Table 1.

Physical and physiological profile of the study participants has been presented in Table 2. Mean BMI of the study participants was 21.4 kg m^{-2}. In terms of mean BMI, the study participants were in 'normal weight' category as per the classification given by WHO (2000). This finding was in consonance with the findings of the earlier study reported that regular physical activity in a designed and methodical manner helps to decrease the chances of becoming overweight (Chatterjee et al. 2015b).

Working environmental condition was assessed in terms of WBGT index (°C), CET (°C), and DI (°C). Working environmental condition throughout the working spell has been presented in Table 3.

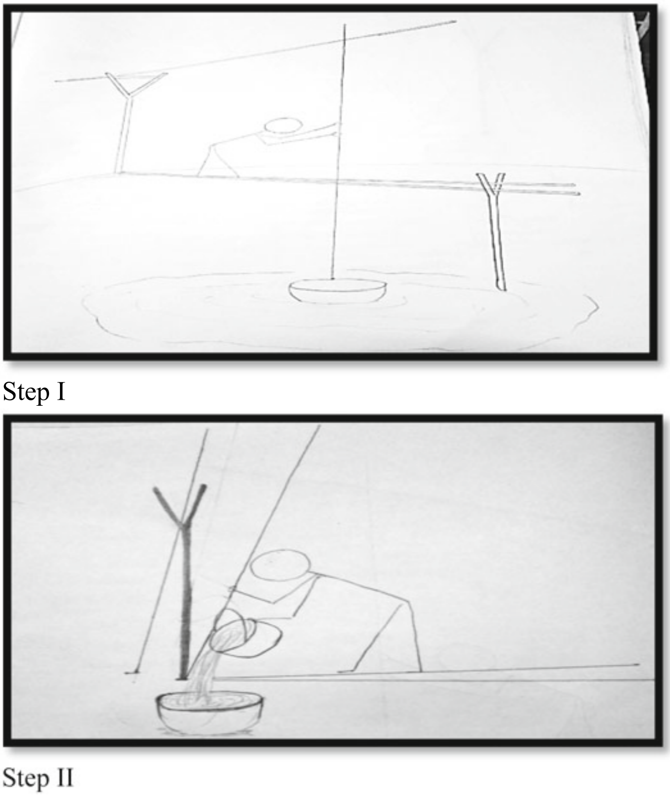


Fig. 1 Line diagram of water-lifting task

Table 1 Basic profile of the study participants

Variables	Values
Age (year)	29.2 ± 4.71
Ethnicity	Bengalee
SES	Lower middle
Work experience (year)	8.1 ± 2.71
Working time (hr day^{-1})	6.8 ± 1.09

Data were presented in AM ± SD

Physiological strain in terms of HR_{Peak}, NCC, and EEE of the study participants has been presented in Fig. 2.

Heaviness of workload has been presented in Table 4.

Table 2 Physical and physiological profile of the study participants

Variables	Values
Stature (cm)	162.7 ± 2.15
BW (kg)	57.8 ± 1.67
BMI (kg m^{-2})	21.4 ± 2.31
$HR_{Pre\text{-}work}$ (beats min^{-1})	74 ± 4.51
$SBP_{Pre\text{-}work}$ (mm Hg)	118 ± 7.12
$DBP_{Pre\text{-}work}$ (mm Hg)	78 ± 4.52

Data were presented in AM ± SD

Table 3 Thermal working environmental condition

Indicators of thermal environmental condition	WL-A		WL-B	
	Spell 1	Spell 2	Spell 1	Spell 2
WBGT (°C)	28.7 ± 1.11	34.2 ± 1.17	21.1 ± 1.01	24.0 ± 1.15
CET (°C)	26.9 ± 1.05	32.1 ± 1.17	19.5 ± 1.10	23.5 ± 1.17
DI (°C)	28.2 ± 1.51	34.1 ± 1.13	20.8 ± 1.71	23.9 ± 1.67

Data were presented in AM ± SD

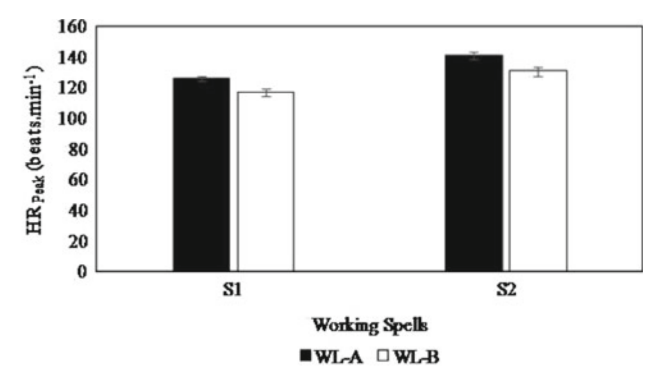
4 Discussion

The present study has been carried out village in and around Selampur, Hooghly district. In terms of BMI, all the study participants were belonged to 'normal weight' category as per the classification given by WHO.

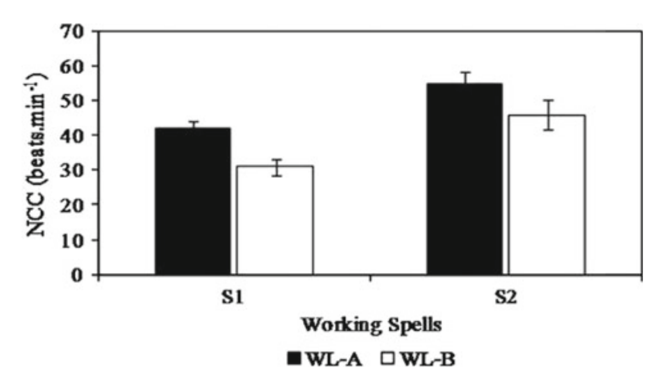
In terms of thermal working environmental condition adjudged by three popular heat indices—WBGT, CET, and DI.

WBGT index values during WL-A and WL-B

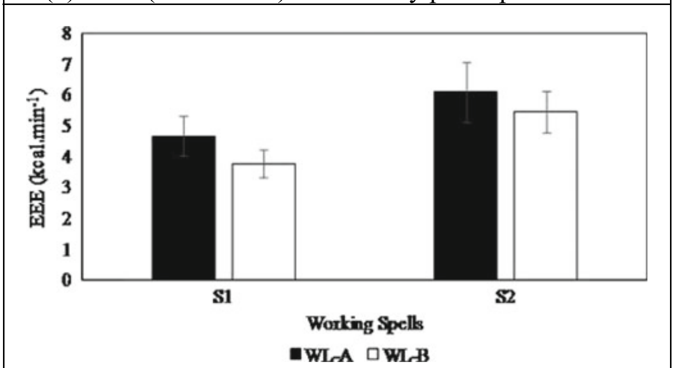
In case of manual WL-A, i.e. water-lifting task during 'Aman' type of paddy cultivation time, the average value of WBGT index in S1 and S2 working spells was 28.7 and 34.2 °C. Of which S1 working spell (28.7 °C), for 'light' type of work, there is no restriction in terms of allocation of work in work rest cycle, for 'moderate' type of work, up to 75% time of each hour, work could be allocated in work rest cycle and for 'heavy' type of work, up to 50% time of each hour, work could be allocated in work rest cycle. On the other hand, during the S2 working spell (34.2 °C), no work is ideally allowable (American Conference of Governmental Industrial Hygienists 2008). In case of manual WL-B, i.e. water-lifting task during 'Boro' type of paddy cultivation time both in S1 and S2 working spells no restriction in terms of allocation of work in work rest cycle.



(a) HR $_{Peak}$ (beats.min^{-1}) of the study participants



(b) NCC (beats.min^{-1}) of the study participants



(c) EEE (kcal.min^{-1}) of the study participants

*P<0.5

Fig. 2 Indicators of physiological strain of the study participants

Table 4 Heaviness of workload

Working spells				
Indicators of physiological strain	WL-A		WL-B	
	S1	S2	S1	S2
HR_{Peak} (beats min^{-1})	H	VH	M	H
NCC (beats min^{-1})	RH	H	M	H
EEE (kcal min^{-1})	H	VH	M	H

M—Moderate, RH—Rather Heavy, H—Heavy, VH—Very Heavy

CET index values during WL-A and WL-B

The average values of CET during 'Aman' type of paddy cultivation time were 26.9 and 32.1 °C in S1 and S2 working spell, respectively. In the S2, with CET value of 32.1 °C, up to 'light' type of work is allowable. In S1 (with average CET value of 26.9 °C) up to 'moderate' category of work could be carried out (WHO 1967). During 'Boro' type of paddy cultivating time, average values of CET in S1 and S2 working spells were 19.5 and 23.5 °C, there is no restriction for carrying out of the task.

DI values during WL-A and WL-B

During the 'Aman' type of paddy cultivating time with an average DI values in S1, and S2 working spells were 28.2, and 34.1 °C. Of which in S2 working spell heat load is considered 'severe', and human resources engaged in physical work are at increased risk for heat illness. In S1, the head load is considered 'mild' and individual can perform physical work is performed with some difficulties. During 'Boro' type of paddy cultivating time, the average DI values in S1 and S2 working spells were 20.8 and 23.9 °C. During S1, and S2 no restriction recommended (Sohar et al. 1962). A significant positive correlation has been found between these heat indices—[WBGT and CET ($P < 0.05$), WBGT and DI ($P < 0.05$), CET and DI ($P < 0.01$)] also indicated the similar thermal working environmental condition. The finding of the present study in terms of environmental condition was in agreement with the findings of earlier studies carried out in the district of Hooghly during 'Aman' and 'Boro' type of paddy cultivation time (Chatterjee et al. 2018a, b, c, 2019a). From the result of the present study, it has been clearly observed that the individuals working in the agricultural field would feel very hot and uncomfortable most of the day time, especially at around noon, i.e. during the second spell of working hours. A comparison has been made in terms of indices of physiological strain in male paddy cultivators while engaged in different tasks during 'Aman' and 'Boro' type of paddy cultivation time; it has been found that physiological strain was significantly higher during manual threshing; followed by manual water-lifting task, manual plowing, manual transplanting task, manual reaping, and manual parboiling task.

Assessment of heaviness of work

The heaviness of the work is carried out in terms of three indicators of physiological strain viz. HR_{peak} (beats min^{-1}), NCC (beats min^{-1}), and EEE (kcal min^{-1}).

For WL-A during S1 working spell

The heaviness of work in the S1 working spell has been adjudged as 'heavy' in terms of HR_{peak}, EEE, and 'rather heavy' in terms of NCC.

For WL-B during S1 working spell

The heaviness of work in the S1 working spell has been adjudged as 'moderate' in terms of all three indicators.

For WL-A during S2 working spell

The heaviness of work in the S2 working spell has been adjudged as 'very heavy' in terms of HR_{peak}, EEE, and 'heavy' in terms of NCC.

For WL-B during S2 working spell

The heaviness of work in the S2 working spell has been adjudged as 'heavy' in terms of all three indicators.

From the result of the present study, it was clearly observed that the individuals working in the agricultural field would feel very hot and uncomfortable most of the daytime, especially at around noon during S2 working spell during 'Aman' type of paddy cultivation time. The finding of the present study is in tune with the finding of earlier study carried out in the district of Hooghly where the paddy cultivators also engaged different tasks during 'Aman' and 'Boro' type of paddy cultivation time (Chatterjee et al. 2015a, c).

5 Conclusion

From the present study, it may be concluded that manual water-lifting task is laborious for the food grain cultivator as indicated from the indices of physiological strain. The physiological strain was significantly higher during 'Aman' type of paddy cultivation time, i.e. in case of WL-A compared with WL-B, i.e. water-lifting task during 'Boro' type of paddy cultivation time. Moreover, the thermal working environmental condition was also not favorable during 'Aman' type of paddy cultivation time making the task strenuous for the food grain cultivators. Modification of work rest schedule, i.e. early starting of the work and/or attempts should be made through design interventions and other means to reduce the extent of strain for ensuring better working performance.

Acknowledgements We are thankful to all the volunteers for their participation and cooperation during the study.

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Chapter 10
"Cognitive Psychology and Student-Centered Pedagogy for Students Creativity: An Analytical Study"

M. S. Balasubramani, Najmuddin Aamer, and Shrikrishna R. Sonawane

1 Introduction

Together, we need to create such a world, "Where there is no scarcity for intelligent honest people, so let's make each child to be one among them." The aim of the paper is to show the possibility of increasing the interest and usefulness of universities subjects by implementing the student-centered pedagogy and using the appropriate current cognitive philosophies in which an individual can actively deploy the information to identify the tools and resources available and relevance, how to assemble them and how to manage the process to develop creativity and problem-solving skills. The paper highlights teachers' responsibilities in education and stimulating students to improve their language, reflective and critical thinking, the sense of responsibility, and accountability toward their goals. "While many research-based learning and cognition principles are readily applicable to student-centered, the constructivists suggested basic shifts in both beliefs as to the locus of knowledge and educational practices" (Jonassen 1991).

2 Literature Review

The followings research articles are referred to add more colors and weightage to the work:

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N. K. Rana et al. (eds.), *Technology Enabled Ergonomic Design*, Design Science and Innovation, https://doi.org/10.1007/978-981-16-6982-8_10

(1) The paper emphasizes that teachers have the ultimate authority to make students - learning independently, hands-on practice to understand the experience and the change of behavior and to develop their critical thinking and problem-solving at student-centered classrooms.
(2) The paper advocates active participation by language-mediated learning activities in which students construct understandings by experiencing collaborative learning, experiential learning, problem-based learning, etc.
(3) The authors examine the applicability of current cognitive principles that provides students to influence their responsibility in determining goals at the student-centered learning and they also critically analyze the issues of its sources from the web-based multimedia.
(4) The Bologna process encourages "Student-centered Learning for higher education and guides the institution a philosophy of greater transparency and emphasizes placing students at the center of their thinking and be able to design consciously and constructively to manage their expectations throughout their experience.
(5) The paper reviews some general guidelines for applying cognitive science principles for active learning and discovery at student-centered classrooms. It also encourages developing e-learning applications and employing state-of-the-art multimedia technology to meet students' expected training potential.
(6) The International Baccalaureate emphasizes the essential of implementing student-centered and constructivist learning approaches for supporting the development of "whole-person" through cross-cultural understanding with higher order skills—critical thinking, creative-thinking, meta-cognitive and self-regulation, social and affective skills.
(7) The paper highlights that the American college graduates do not possess enough skills as per the views of business community because they are treated as an average student and are provided with the same standardized education regardless of their background, abilities, or interests by the tenets of Taylor's scientific management.
(8) The study reveals that the exam oriented curriculum, class sizes are the main barriers practicing learner-centered approaches so it suggests the learning disabilities should get learning opportunities through active participation.
(9) The essay portraits the reason of draining cognitive resources and depicts that the students' ideas and skills to be developed through practice, hard work, and put efforts into projects to generate more growth and mindset to have better results in education.
(10) The authors show that the human physiological response continues to reflect the demands of earlier environments and it can modify various features of the immune response such as threats, stress, and immunity in humans.
(11) Attila Olah developed 16 Psychological Immune Competence Inventory in 2000 and introduced a new concept "Psychological Immunity" and Psychological Immune System's working model to strengthen immunity and ego-resilience *to raise individual's capacity.*

(12) The research emphasizes that the incorporating of "Language Learner Immunity" will help the learners of Iran gaining the ability to overcome the psychological hindrances and in turn it might lead them to effective in learning the English as a Foreign Language.

(13) The paper presents the suggestion of Neuroscience research between individuals and depicts the resilience can be built up through education with life-long possessions to have exciting knock-on effects, comfort, health, employment, and the economy.

(14) This paper concentrates on theory of behaviorism and highlights Pavlov, Thorndike, Watson, and Skinner views that all behavior is established by stimulus–response associations through conditioning.

3 Language and Knowledge to Enjoy Education

(A) Human Being made literature to leave their thoughts to their future generation. The literature was preserved and communicated through the cultural vehicle of languages. The languages of literature are possible to learn and learning more languages helps to know the culture of the languages and of the societies. The knowing culture improves your knowledge so wide that inculcates the character, the attribute, and the quality which are considered as an art. The art is an essential component of life to make learning pleasurable and delightful.

(B) Knowledge is the historical product of socio-cultural processes. The acquisition of knowledge and art are essential requirements of life and it is possible to obtain only through education. "Students should endeavor to awaken the divinity and perfection within them through the acquisition of knowledge" (Swami Vivekananda). Education means active participation with language-mediated learning activities at institutions where occurs the change in performance to assist students becoming a better human being. This situation imparts holistic learning and other skill set to students to get 100% success in physical activities that make learning enjoying and gaining knowledge as well as knowing how to apply the knowledge to achieve their goals. "Education is not the learning of facts, but the training of the minds to think" (Albert Einstein 1879–1955).

(C) Process of Education Education is a continuous process by yourself, at home, school, and environment. The process starts from the learning that creates passion to concentrate at one thing and its application to bring change in behavior and skills for achieving the vision and mission. If it is not happened, the education is considered as unsuccessful. The following Fig. 1 is the process of education:

Fig. 1 Process of Education

(D) Process of Learning: Learning is a search for meaning and it must start with the issues around of us so that the learner can actively try to construct the meaning of the part as well as the whole. It can be briefly understood by this Fig. 2.

These four words are interconnected with each other and its processes are very important in learning and attaining Cognitive Skills—*paying attention to find out the meaning of the content and its relevance which helps you to learn it fast and store it in mind (memory) and to document the comprehensive report to expand the capacity of learning*.

The learning is not about accumulating lot of knowledge, but it is about physical training in many, many ways like hearing as a physiological act and listening as physiological training. For instance, human brain has filters which allows the familiar sounds in and filter out the unfamiliar sounds. This process defines that if you cannot understand a sound, you are not going to learn it. Thus, able to hear the sound and keep practice on is known as physiological training.

Everyone's need is an opportunity to learn and prove his/her talent and creating opportunity is possible by own self or from someone else or through the process of education. The learning ability and the life experience cultivate the change of behavior which is rooted from cognitive psychology that is known as **Being Educated**—*interconnection of mental, emotional, and physiological stimuli* and **Acting Educated**—*the experimental learning of observing, doing, and living through things*. "The Blooming Taxonomy (Cognitive, Affective, and Psychomotor Domains) depicts that the learning objectives are related to an individual behavior from the life experience."

(E) Language Competency: The difference between the words and its tone can be possible to define by the language of love and understanding of the body language. Traditionally, languages were taught through grammar that typically shows how sentences should be organized. It is of course an important part of language ability, but the aspect of language knowledge really works with the ability of creating accurate sentences which is known as linguistic competence. This competency enables your capacity of using appropriate language *for the context, for the situation, for the participants,* and *for the relationship between them* and improves your communication ability. "Researchers have noted that students failed to develop theories of explanations and retained initial misconceptions" (de Jong and Van Jooligen 1998), to reflect or "enact meta-cognitive process" (Atkins and Blissett 1992).

The distinction between linguistic competence and communication ability is reflected in **Jack C Richards'** five strands—*Accuracy, Fluency, Complexity, Appropriate, Capacity*. These strands explore different ways of functions like focus on tasks, focus on distinction between fluency and accuracy, and focus on different texts in different contexts which are very important in teaching a language and to

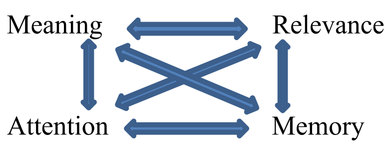


Fig. 2 Principles of Learning

know *how to construct correct sentences and to develop the capacity of how to create sentences,* and *the capacity of acquiring the use of these capacity to improve their communication ability* and *building rapport with others.*

(F) Theories of Psychology Perspectives

(i) Researchers have classified the characteristics of trained communicators into five areas such as (1) *Self-awareness*, (2) *Adaptability*, (3) *Empathy*, (4) *Cognitive Complexity*, and (5) *Ethics*. They have also mentioned that in different sociolinguistic contexts, in addition to these characteristics they need to have the following qualities to become intercultural skilled people:

- Having extensive knowledge of the culture and a great deal of interaction with members within the culture.
- Open-mindedness and ability to change behavior to fit cultural expectation.
- Fluency of primary language or languages.
- Knowing the content appropriate to situation with appropriate behavior.
- Understanding and managing conflicts and high tolerance for uncertainty.

(ii) Sigmund Freud divided the mindset into 3 basic parts as follows:

1. **The id** represents a person's basic survival drives like food, sex, and sleep.
2. **The ego** represents a person's sense of self and grasp of the outside world.
3. **The superego** handles higher moral concepts like the concepts of right or wrong.

In his essay *Beyond the Pleasure Principle*, he described that *the passionate and love* and *the pleasure principle* neglect everything except for the immediate fulfillment of its desires (*short-term*) and *the reality-principle* focuses more on *the long term.*

(iii) Jacques Lacan said that the desire doesn't merely refer to your needs and wants but arises from an existential lack (a gaping hole) and it can never be attained the equilibrium. It is actually the constant discomfort of your desire that drives your pleasure. The cognitive distortion such as *negative attitudes, self-defeating thoughts* affects your feelings and behavior which create poor motivation to learn and to overcome this situation, teachers, and students should probably read books on cognitive theory to motivate themselves in studies and to reach full human potential.

4 Educational Psychology and Cognitive Science

(A) Educational Psychology is concerned with the study of teaching psychology and social psychology of schools and organization and how human learn a wide range of educational trainings in these settings with effective participation.

(B) Cognitivism was developed by Jean Piaget in 1920s. Cognitive means *conscious functions* in human brain. Miller and Bruner founded the Harvard Center for cognitive studies in 1960s. Aaron Beck originated Cognitive Theory of Counseling and David Burns and others expanded on and provided a model to identify the negative and to replace it with healthier perspectives in higher education.

(C) Cognitive Science means the study of process of mind scientifically which began in 1950s as an intellectual movement and often referred as a cognitive revolution. Its tasks are to examine the nature and the functions of cognition, and processes of transformation of information.

(D) Cognition is mental processes like thought, experience, and senses used for understanding and acquiring knowledge. It also alters the acquired knowledge as existing knowledge and/or generates new knowledge through incorporating the intellectual functions such as *attention, the formation of knowledge, memory and working memory, judgment and evaluation, reasoning and computation, problem-solving and decision-making, comprehension, and productions of language*.

(E) Cognitive Theory is an approach to psychology that attempts to determine human relations such as *Personal factors*, *Environmental factors*, and *Behavior* by understanding the thought processes like *Perception, Attention, Language, Memory, Thinking,* and *Consciousness*. The personal factors are *knowledge, expectation,* and *attitudes*; the environmental factors are *social norms, access in community, influence on others, openness to change*; and the Behavior are *skills, practice,* and *self-efficacy*. You can see the same in the following Fig. 3.

The processes of three human relations of the diagram are:

(1) The thoughts and actions influence an interaction between a person and his/her behavior.
(2) The social influences develop and modify beliefs and cognitive competence which impact the interaction between the person and the environment.
(3) The interaction between the environment and their behavior involves the person's behavior determining their environment, which, in turn, affects their behavior.

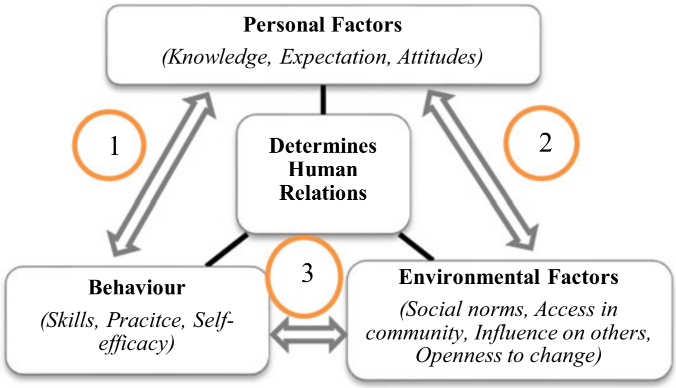


Fig. 3 Cognitive Theory

5 Cognitive Psychology

(A) Cognitive psychology is abided with two basic principles such as the study of **Mental Processes**—*learning, language development, memory* and *mental problem-solving* and the **Complex Behaviors**—*aptitude, practice,* and *self-efficiency*. The teachers' and curriculum developers' knowledge of *cognitive psychology* helps them to study the development of students and their brain processes, learning and retaining of information. It can also be helpful for other professions like linguistics, artists, doctors, psychologists, engineers, architects, software designers, speech therapists, scientists, and neuroscientists.

(B) Cognitive Approach starts with three assumptions of internal mental processes that influence behaviors as given below (Fig. 4).

Let's see the cognitive psychologists' three main methods of study of the mind:

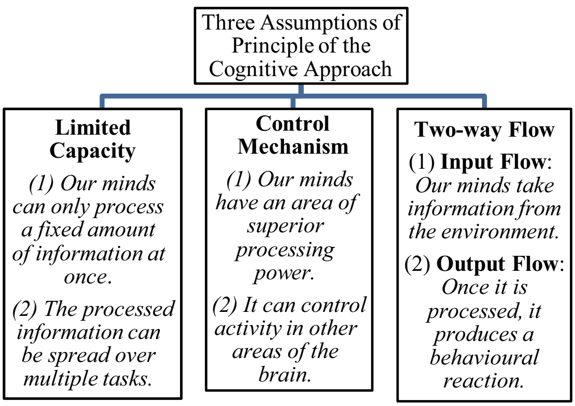
(1) **Laboratory Experiment**: It is the most popular method structured with *research, experimenting variables,* and *finding a scientific and valid way* to the study of the mind.
(2) **Case Studies**: It can give an insight into the working of mental processes that focuses on rare occurrences like brain damage or trauma. It can be less reliable.
(3) **Brain Imaging**: It is the more recent cognitive methods and super interesting and far evolving area of Psych. The high-tech scanning machines—MRT or PET are used to map the specific cognitive functions of the brain.

Let's see the two features of cognitive approach:

(1) Theoretical Models enable the representation of complex cognitive processes. Atkinson and Shiffrin (1968) proposed a Multi-Store Model (MSM) that consists of three stores as given in the Fig. 5.

In MSM, the information moves under the control of various cognitive processes such as (1) *Attention*, (2) *Rehearsal*, *and* (3) *Retrieval*. These processes happen to you due to your emotional content, needs, desires, drives, etc. which is often quiet, hidden from your conscious mind. The subconscious mind can have as much or

Fig. 4 Principle of Cognitive Approach



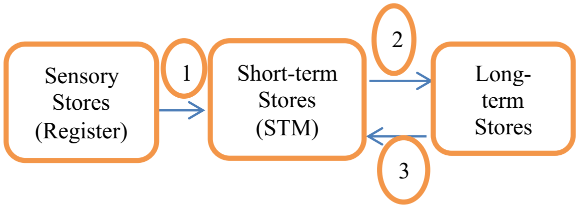


Fig. 5 Multi-store Model (MSM)

more control over what you do as your cognitive mind. It also causes you to '*act up*' or '*be unproductive*' because they don't completely understand or distracted due to inner pains, needs, and feelings. It can be resulted more orderly and successfully in classroom activities if the teacher consciously evaluated your behavior.

(2) Schema Theory The schema theory emphasizes how perception and memory are shaped from *experiencing* the *interpretations of information in the brain.* This information allows you to predict future possibilities like the sense of an uncertain world by "*filling in the gaps*" in your knowledge and thus enable you *to act comfortably* even when our information is incomplete. There are three types of schema and its details are as follows:

(1) **Role Schema** concerns expected behavior for someone in a role. For instance, you might expect the queen to always be well-mannered and drink copious amounts of tea; and the other is an athlete to be fit and energetic.
(2) **Event Schema** which is also known as "Scripts" relates to what is expected in a situation on. For instance, putting paste on brush and brushing your teeth, and turning out the lights to get into bed, etc.
(3) **Self-Schema** is about yourselves based on your look, personality, and values, but for you or I, it is more likely to include values such as being a psychology student, sibling, friends, and tea lover.

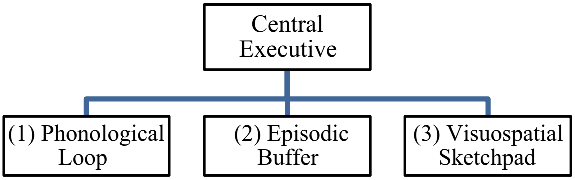
How does the schematic process work?

When we come across new information, it does not fit with our existing context. Then, the new information incorporates with the schema in one of the two following ways:

(1) Assimilation: The new piece of information incorporates into an existing file so that the original schema remains the same. For instance: When a child listens "cat" a four-legged animal, this creates a new schema about what a cat is. This would lead to other four-legged animals like "a lion" also being assimilated into the schema.

(2) Accommodation: That the new piece of information is accommodated into the schema when the file is adapted to incorporate the new information, in turn, the existing schema is altered as a result of new information. For instance: the child may later learn that although a dog has four legs, it does not actually fit in the cat schema. So, the schema is changed or accommodated to reflect this. "The existing schema would affect someone's memory of an unusual event" (Barletta 1932).

Fig. 6 Working Memory Model (WMM)



(C) Cognitive Learning Principles (CLP), which are based on plans, active approaches, and profitability, can help *to restore order and how to utilize them effectively* in modern-day classrooms where students apply conscious thoughts to learning activities and behavior for motivation and more profitable results. The CLPs focus on your act and thought processes to connect them into what you know (memory) rather than your response to stimuli (happening and feeling) by "*connecting the dots*" of new information with previous information. It tends to make you a more effective learner.

(D) Working Memory Model (WMM) is a short-term memory. It proposes every component of working memory that has limited capacity and that the components are relatively independent of each other as follows (Fig. 6).

(1) Phonological Loop's one process is speech perception and stores spoken words we hear for 1–2 s which is known as *Phonological Store (inner ear)* and other process is speech production and rehearses and stores verbal information from the phonological store which is known as *Articulatory control process (inner voice).*

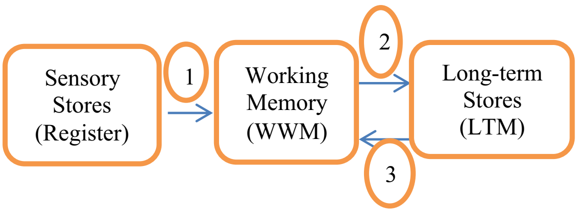
(2) Episodic Buffer is for storing everything.

(3) Visuo-spatial Sketchpad holds visual or three-dimensional information.

The WMM is used in place of STM in the MSM because it is better than that and looks more at processes and gives more than one way of transferring information (Fig. 7).

The three basic cognitive processes are as follows (1) *Perception*, (2) *Attention*, and (3) *Memory.* These are mental operations of thoughts which help us to adapt to the environment by *thinking, knowing, remembering, judging,* and *problem-solving*. These are higher level functions of the brain that encompass *language, imagination, perception, and planning* to avoid certain cognitive impairments such as *confusion, poor-motor coordination, loss of short-term or long-term memory, identity confusion,* and *impaired judgement*.

Fig. 7 Working memory replaced STM



6 Mind, Brain, and Education

The phrase "All is Mind" depicts the relationship of mind's category such as consciousness, subconsciousness, unconsciousness, and its distinctions. Traditionally, the Principle of Mentalism defines that the mind dominates the brain and the spirit and to realize it one must know about his/her inner strength and control of reality.

(A) The Conscious Mind is equal to seen which means the choice and awareness of things and its connection universally. The subconscious mind and the unconscious mind are equal to unseen, which is not so clear and illogical, protective, and creative. The first one is subjective mind related to the intelligence of memory, personality, and character and the second one is equal to world's objects and nature and governing pattern of life. It is said that conscious is flashlight, subconscious is darkness, and unconscious is the total world. "Until you make the unconscious conscious, it will direct your life and you will call it fate."—Carl Jung.

(B) Mind in Succeed is e*ase into your power seizes your life*. "Failure will never overtake me if my definition to Succeed is strong enough" (Dr. Abdul Kalam). The new field of Educational Neuroscience investigates the reaction of biological processes and education. It also explores "'*learning to learn*', *cognitive control and flexibility*, *motivation* as well as *social and emotional experience"* (The Royal Society 2011, p. 1).

(C) Psycho and Physiological Status are needed while learning because it helps you to be tolerant and ambiguity in controlling your mind status such as Alpha, Beta, Theta, and Delta. These states depict your cognitive abilities such as when you are in sad, angry, worried, upset, you are not going to learn in that states but when you are happy, relaxed, you are curious to learn and it happens really quick and very specifically.

(D) Alpha State of Mind reflects the "*right brain*" activity, and *subjective senses of imagination, memory, intuition,* and *creativity*. The resting state of the brain is an alpha brainwave that dominates quietly flowing thoughts and also *aid overall mental coordination, calmness, alertness, mind/body integration,* and *learning*. Alpha waves are possible to create by doing yoga and exercises.

(E) Binaural Beats are the processes of your brain. It falls gradually into synchrony between the Hertz (Hz) of two frequencies of tones. For example, when we hear two tones, one in each ear, with *122* and *110 Hz*, our brain processes the beat differences of *12 Hz* ($122 - 110 = 12$) and makes to hear a tone at **12 Hz** instead of two different tones. These auditory illusions are considered as binaural beats and it can be between 1 and 30 Hz. It helps you to tune instruments and create the frequency needed for your brain and to connect potential health benefits that one would experience during meditation. The binaural beats claim reduction of anxiety, increase focus and concentration, lower stress, increase relaxation, foster positive moods, promote creativity, and help manage pain.

The following Fig. 8 depicts the frequencies of different brain waves of different action within one-second distance:

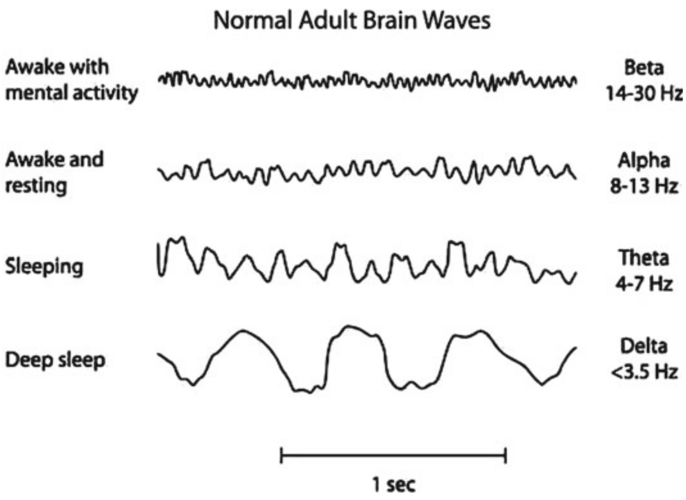


Fig. 8 Frequencies of brain waves in different actions

In Beta frequencies (14–30 Hz), the binaural beats are related to awaking the mental activity such as *increased concentration and alertness, problem-solving* and *improved memory*. In Alpha frequencies (8–13 Hz), the binaural beats help to awake the thought process to encourage *relaxation, promote positivity* and *decrease anxiety*. Theta (4–7 Hz) represents *sleeping* and Delta (<3.5 Hz) represents *deep sleeping*.

(F) Neuroplasticity allows your brain continuous to take an account of environment and stores the results of learning in the form of memories to prepare you facing the future events based on your experience. The changes in the brain's structure and connectivity suggest that there are sensitive periods in brain development extending beyond childhood into adolescence. Human learning abilities vary, in the same way, that human height and blood pressure vary. (The Royal Society 2011, p. 5). Dynamic changes to brain connectivity continue in later life (The Royal Society 2011, p. 6).

(G) Behaviorisms and Cognitive Behavior Therapy states all behaviors, which are learned through interaction with the environment and through a process that known as conditioning. *The fathers of behaviorism theory Pavlov, Thorndike, Watson, and Skinner believed that all behavior is established by stimulus–response associations through conditioning*. Learning about the mental health is crucial for all of you that make you to imagine a better future for everyone.

(H) Cognitive Behavioral Therapy (CBT) is an evidence-based treatment focusing on the relationship of thoughts, feelings, beliefs, and behavior which can help you to deal with depression, anxiety, panic attacks, hard-relationships, and many other problems. The CBT helps to rethink and reexamine how to see the world, and how to shut the negative thoughts down by teaming up with strong emotions which intellect to have clear thoughts and feelings for a fearless inventory and hard work for thinking more productively. Then, you will feel that you are on the road to learn along with an action and to put the pieces together to create a product.

(I) Having Become Conditioned is a preconscious content potentially be brought into conscious minds such as the thoughts, memories, feelings, and wishes that make you aware at any given moment and you can think and talk about rationally. In general, people's awareness of consciousness is high in rate and subconsciousness and unconsciousness are low and these two dominate their bravery and curiosity and become masters of their destiny. "There is another part of your mind that is more mystical called the *unconscious* (Sigmund Freud), and the *subconscious*" (Pierre Janet). The conscious mind is what you aware of and the subconscious aspect is which you are not even aware of. The awareness of knowledge needs practice because it influences your habits which constantly make you involuntarily respond to situation without analyzing. In other words, it is known as *Having Become Conditioned*. ***For instances***:

1. Fleas can jump 16 feet. If you put it into a tin box of one-foot space, it keeps on jump few times up to that level and then it will realize that it cannot jump more than one foot. Later, it never tries to jump more than that when it is out of the box because it is *having become conditioned*.
2. Similarly, when a big elephant, which has huge power, is tied with a small thread on a stick of tree that attached to the ground, it does not try to yank it because when it was small, it was tied in this manner and it tried to yank continuously but couldn't. Then, it set its mind that it couldn't do that at any time. Now, it has grown up, but it doesn't try because it is *having become conditioned*.
3. In the same way, the scariness of darkness from your childhood is embedded in subconscious mind; whenever you face darkness, you become scared and keep on struggling consciously because your behavior becomes conditioned.

Practically, 90% of your behavior and thoughts are determined by subconscious mind and your conscious choices are few and far between. So, remember that "all is mind" which means "all is one" and it could be realized through changing your inner self and by understanding the hidden laws of nature. So, remember that your experience manifests your will power and truth.

The self-practice of your own mantras encourage greater radiance, inner peace, and equilibrium by simple attuning to a specific Chakras as follows:

(1) **Root Chakra (I am)**: Root Chakra helps to understand your foundation emotional and physical status that cements your relationship to your natural characteristics.
(2) **Sacral Chakra (I feel)**: Sacral Chakra helps to couple your feelings for balancing your energy on moving with peace and elegance and becoming more expressively creative and emotionally stable.
(3) **Solar Plexus Chakra (I do)**: An action of personal drive channels your authentic power to inspire and radiate from the inside out which brings forth direction to your life with speaking truth.
(4) **Heart Chakra (I love)**: It is a kind of nurturing self-compassion and feminine which produce reflecting and connecting to the heart's virtues which brings the glory of beauty and joy to your life.

(5) **Throat Chakra (I speak)**: You put power into speak and express your true self. It is the ruler of communication that reinforces the expression of your individuality. Balancing the ether sound element of the throat helps you to welcome the dark and light within each of you, polarizing the duality you all live in.
(6) **Third Eye Chakra (I see)**: This practice requires a powerful use of trusting in yourselves that allows you to view the inward connection that exists within each of you. It reflects your intuition and innate wisdom which allows you to perceive beyond your physical eyes.
(7) **Crown Chakra (I understand)**: It connects you to realm—a state of higher consciousness and times, to practice the trust and oneness in your extensive journey. It also motivates continuously seeking to learn more.

(I) Constructivism theory that says that the learning is based on knowledge construction by mental activity and it considers that the learners are active organisms in seeking meaning. Each one constructs his/her own understanding of the world consciously and generates own "rules" and "mental models" to make the sense of experiences and accommodation of new experiences. The properties of constructivism are defined by "The Physics Education Research Group of University of Massachusetts" as follows:

1. Knowledge is constructed, not transmitted.
2. Prior knowledge impacts the learning process.
3. Initial understanding is local, not global.
4. Building useful knowledge structures requires effortful and purposeful activity.

According to constructivists, individual meanings are constructed through personal interaction with the world rather than assimilations (Philips 1995). A constructivist teaching strategy beliefs that the education connects themes and concepts rather than isolated information. Students learn best by active learning, encouraging thinking and explaining their reasoning instead of textbooks, memorizing and reciting facts (The Royal Society 2011). "Knowledge is actively constructed by the learner, not passively received from the environment" (Jean Piaget).

(J) The Cosmos is a visible leader and the mind is an invisible leader to run this world smoothly. Your dream connects you to many things of past, present, and future of your life, but your soul reads the layer of the mind which is not possible to read by conscious. The internal power continuously works to influence both your mind and body to gain finite energy, infinite zeal, courage, infinite patience for achieving great things in your life. Thus, set your mind to cope with environment for thinking and attributing habitual one and devotedly commit yourself and dedicatedly set apart a system of life. When an action and reaction happen, your brain gets quite familiar, quite quickly just and think of them as power of energy.

7 Requirement of Student-Centered Pedagogy

(A) Behavior Management: Classroom management is one of the arts in which teachers' behavior plays very important role to maintain relationship between the teacher and students and peer's relation. The teaching methodology primarily falls into two approaches (1) Teacher-centered learning and (2) Student-centered learning both refer to the general principles, pedagogy, and management strategies for classroom instruction (1).

(B) What had been done in the past?

India's Gurukul, the epitome of Indian style of learning in natural environment, was considered as a student-centered pedagogy where the guru/mentor and shishyas/disciples sacred tradition was upheld to the focus on "*the broad concept of Spiritual Intelligence.*" It is a core heritage of Indian culture with room for many perspectives such as a sense of connection to something bigger than human being, and a search for meaning in life universally. It is a universal human experience that touches all and imparts learning with cultured and disciplined life, love, brotherhood, and humanity.

Here, the disciples not only taught with language, mathematics, sciences but also arts, sports, crafts, and singing. All these were taught through practical and everyone did hands-on practice and then words were given for chanting. Later, they learnt it through self-learning and group discussion that developed their intelligence, critical thinking, and problem-solving. There were some mandatory daily chores such as yoga, meditation, and mantra chanting for generating positivity and peace of mind to make them fit in practical skills. Overall, the Gurukul developed their personality, increased their self-confidence, sense of discipline, intellect, and open-mindedness which are necessary to face the world and go ahead. "*In student-centered classrooms, students play an active role to make sense of what they are learning and by relating it to prior knowledge and by discussing it with others*" (Brophy 1999, p. 49).

Table 1 Teacher-center versus student-center

Teacher-centered classroom	Student-centered classroom
(1) Students are passive here and respond to environment factors	(1) In student-centered classroom, the participants move from one level to another by experiencing three essential learning elements—*knowledge, skills* and *understanding*
(2) Its approaches are relied on the behaviorist theory	(2) Students explore critical thinking, and problem-solving
(3) Teachers have the primary responsibility to communicate knowledge to students	(3) Students perform and gain the knowledge and keep examination-driven system away

(C) What is being done, now?

Unfortunately, the above concept has disappeared due to Lord Macaulay's modern education system which was brought to India in 1835. It has more commercial in nature like rat race to be ahead of others and a total absence of personality development, creations of moral science, and ethnical thinking. The present education system is more focused on acquiring encyclopedic knowledge rather than promoting problems identification and creativity which leads students not able to analyze the specific situation and stand up for their own opinions to evaluate alternative solutions by using their knowledge with practical applications. These skills are very important to enhance the quality of education at universities and to attract people's attention effectively in their personal and professional life.

In today's education system, the knowledge is in text form and the teacher just presents it orally and asks students to present it commonly without considering an individual's interest. *For examples*:

(1) "What I learnt that day was unique. My teacher gave me an aim in life" (Dr. APJ Abdul Kalam). It is one of the most important events of Dr. A.P.J. Abdul Kalam from "Reignited: Scientific Pathways to a Brighter Future." Kalam says that his science teacher Sivasubramania Iyer once discussed "how birds fly" with a sketch of a bird and the same day he took the class to the Rameswaram seashore to show a live demo of birds flying and explained its flapping wings, using wings and tail to change direction and the locomotive force behind this flight which is the life energy of the bird. He also told that the same principles make an aircraft fly. That single lecture transformed Kalam's life and led him to his passion: rocket engineering and space flight which earned him a nick name "Missile Man". This is one of the best examples for student-centered learning.

(2) A trainer asked the different kinds of animals to claim on a tree or swim in the water. Tell me, it is possible to an elephant! Similarly, students are different by their mind and talent. "Constructivist and student-centered approaches are very important to support and achieve the educational objectives. Students are smart in different ways and have different learning approaches; thus, the student-centered approach becomes a necessity to account for different learning styles in the classroom" (Hudson 2009). Some students are good in arts, sports, drama, acting, reading, speaking, etc. but they are unfairly tested in the common pace! "It also includes musical, interpersonal verbal, logical and intrapersonal activities. The eight major intelligences (logical-mathematical, linguistic, visual-spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalist) have been shaping the curriculum, pedagogy, and assessment in many ways over the last two decades" (Armstrong 2009).

(C) What should be done, further?

(i) Art and Entertainment: When students take any concept, they try to learn it and develop into a project and its presentation. It is only limited by their imagination. If they include a skit or video clip or model or poetry of any art and entertainment for demonstrating their talent, their imagination could lead them for an unlimited artistic performance.

(ii) Learning Modalities: The last two decades' most employed learning modalities are

(1) **Visual**-based observation for learning.
(2) **Auditory**-based listening for collecting information.
(3) **Kinesthetic**-based learning to understand movements, for example, hand-on practice and engaging in activities.

Gardner's 1983 Multiple Intelligences (MI) theory which has had an impact on education around the world and Stemberg's 1999 theory put more emphasis on delineating different theories with different taxonomies which usually describe human intelligence on cognitive, meta-cognitive, affective, and socio-cultural dimensions.

(D) Requirements to obtain knowledge: In teaching methodology at student-centered training the following **Six Cs** are required:

(1) Choice: Choice helps students wired to free will. Either school or college, they love having choice. Let students have choices and make it as a big part of the classroom and they will achieve the required objectives of the subject. Teachers should give priority to students choice and to meet many diverse learning styles. For instance, Once, I observed some of my students at a conference lunchroom; they loved having their own choice of food and enjoyed eating without wasting the time and food.

(2) Collaboration: Collaboration makes you equipped to be social creatures and takes your past knowledge connect to new knowledge. The modern world has a lot of educational tools such as computer tutorials, educational videos, PPTs, and websites. You know that saying, "A picture is worth a thousand words" which depicts that accompanying these tools in classrooms tends students to choose the way of learning and simulation. They may use "reflection sheets" which help them to think about their learning, self-evaluation.

(3) Communication: Communicative efficiency is more important to share the message across consequently and to build rapport amongpeople. Internationally, English has become lingua franca so, adhering to using only English in participative-learning improves student's English fluency and confidence that leading them to present their talent efficiently.

(4) Critical Thinking: Critical thinking requires teachers to remove themselves from the frontand center instead of these be as a guide to nurture their inspiration. This opens opportunities to not merely teach but to coach, to mentor, to nurture, and inspire students for problem-solving. Got to love students, which is not warm, fuzzy, emotional love but genuine, decisional put-the-other-person-first, motivates and inspires a powerful way and allows teachers to meet a group of students to listen their thinking and to respond their questions. This situation creates somewhat of a teacher paradox and he/she may seem to become less important but ironically the teacher becomes more important as he/she working as a guide on the side. "*A great teacher thinks like a kid but acts like an adult*."

(5) Creativity: Creativity makes students uniquely human and to achieve this the followings are important: a lesson plan, well-organized activity with discipline, effective use of language and technology, and the standards but please don't let students suppress their creativity. A great teacher understand that students have a life outside of institutions, so he/she helps students if they struggle and won't do any assumption about the kids. Teachers wait and watch, and they rescue students when they are stuck. Students simply be happy or become worried because they often think that they are going to be judged and the listener going to point out their mistakes or failures. So teachers must encourage them to create an impression on the other person with high hopes by their will power and confidence. They must guide them to do a lot of practice and educate them not to worry about mistakes or failure because it leads them to creativity.

Let go off the fear: The universe has all the blessing for you and its rich energy flows into you in many forms such as love, affection, friendship, and material possessions. It is very important to keep your consciousness open to receive these all and assure yourself to keep away your fear or insecure or worried that occasionally cuts off entering the wonderful flow of universal energy in you.

(6) Caring: Caring inspirits students to pay attention effectively and to get self-movtivated. It makes students to remember always their teacher by the following:

- Looked students in the eye and eased them with intonation and asked them how they were doing.
- Asked about their extra-curricular activities and went to their athletic events and their concerts.
- Informed them about internships and part-time jobs.
- Instead of impression brought expression with transparent and real sense of laugh and laugh with them.
- Showed openness in evaluation.

(E) Student-centered Training Assessment goes on together with the teaching–learning process. Evaluation is based on the principle of comprehensiveness in examination but the assessment is different from examinations and it is a continuous process to make students regular, punctual, and work systematically for the whole academic period. It also provides grades to all the aspects of their personality and talent. For instance, in Engineering subjects of Professional Communication and Ethics and Business Communication and Ethics of University of Mumbai, India, students need to be free for choice and performance of all the activities of the subjects with an environment of student-centered learning and the teacher's support and guidance. In which, they can develop self-motivation to understand their cognition, overcoming their psychological hindrances, and improving their English fluency and employability skills. "Swami Vivekananda said that the Vedanta teaches '*Nirvana—the realization of the Self*' and once known that you never again can be deceived by the illusion of personality."

In this environment, "A good many things of the participants can be assessed by the teachers *silently*, because the teachers focus on the behavior of the participants and their command over the English language which are unique from the quality point of view. Teachers do not give any importance to the subject matters but justify their applying knowledge and understandings of the different situations, their interests and creativity skills." All these things happened in our teaching experiences by the knowledge of psychology and knowing the value of student-centered pedagogy. "The true Vedanta possesses absolute liberty and unrivaled courage to observe the diverse hypothesis and for coordination. *Each man has been entirely free to search wherever he/she pleased for the spiritual explanation of the spectacle of the universe*" (Romain Rolland in Life of Vivekananda, 1944).

8 Conclusion

This analytical study brings a conclusion that the inference of current cognitive principles, student-centered learning, and a great influence of teachers are the possible pedagogical approaches for encouraging an individual actively work to generate more growth over time and to bring better results in education. This environment with English language-mediated activities gives a chance to everyone to identify the relevant tools and resources to manage the process and develop the creativity. The problem-solving skills and the performance of students develop their English fluency and their involvement and hard work bring out their ideas and skills into a new product. They also learn consciously construction of determining goals, experiencing the collaborative learnings, experiential learning, and problem-based throughout their higher education to meet the goals. This multidimensional unit acts as a protective apparatus to strengthen and to raise the individual's capacity with resilience.

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Chapter 11
Commercial Painting Hazards and Respective Personal Protective Equipments

Padmini Pandey and U. V. Kiran

1 Introduction

In the residential and commercial sectors people would like to spend considerable amount of money for repainting the building. For the repainting, surface preparation is essential which includes sanding, scraping, burning, and peeling or flaking. These all processes ensure that durability will be increased in new paints.

The place of work has always been at threat for injuries, including physical, chemical, and biological risks. The jobs in high threat areas like risky statues, platforms, scaffolds make this painter community highly vulnerable to bone, eye, muscle, and other types of injuries (Pandey and Kiran 2020b). Environmental management system must take a decision to eliminate or reduce such possible factors to enhance the efficiency of workplace in order rescue workers with such form of risk. In fact, though, there are several other workplaces where such firmly active steps are impossible to implement. A work management system using personal protective equipment (PPE) is considered a sustainable and relevant means of ensuring the safety and health of workers in such circumstances (Sawada et al. 2017).

Objectives:

The principle aims of this review are as follows:

(1) It focuses on the hazards during painting at workplace.
(2) It aimed to identify different safety measures during working.

Health risk during painting: Occupational hazard seems to be the threat, damage, or trouble to which individuals are exposed mostly in workplaces, while these occupational diseases result from exposures to the workers (World Health Organization 1986; Packard 1989). As the paint provide aesthetic appearance to the wall, it has

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some disadvantages too like solvent-borne paints have toxicity and instability. Paint pollutant can cause serious hazardous effect on our body like headaches, trigger allergies, asthmatic reactions, irritate skin, eyes, and put increased stress on vital organs which could be temporary or may be permanent (Pandey and Kiran 2020a).

Short-term exposure of aromatic hydrocarbons solvents from inhalation can bring about bothering to the upper respiratory tract and eyes, also dizziness, exhaustion, and headaches. Long-term impact may cause disorders in blood, cardiovascular and kidney effects, unconsciousness, dysfunction of the CNS.

Within the painting occupation, workers have to perform tasks such as

- Surface preparation.
- Mixing raw material and applying it.
- Finishing (WorkSafe 2020).

Working Health and Safety Risks on Site Include:

- Falling from height.
- Accessibility to flammable materials.
- Lifting action.
- Chance of eye damage by airborne particles.
- Risk of cancer by occupational exposures.
- Accidents owing to messy work area.
- Operations for enduring.
- Microorganisms, molds, and bacteria.
- Skin problems.
- Cuts and scrapes.
- Danger of pain or disability from repeated activities.
- Sound sensitivity.
- Harm by objects dropping.
- Threat of liquid eye problem (Health and Safety Advice for Painters Decorators 2020).

Some substances used in the painting industry (organic and inorganic) often contain significant amounts of toxic metals. The manufacturing of paints generally requires a wide variety of raw materials containing toxic heavy metals, cadmium, and chromium pigments, as well as fungicides such as mercuric oxide (Piper 1965) in the manufacturing process, which can cause health hazards, which are often easily identified and others which can remain undetected for many years (Molyneux 1981; Courtney 1996; Cox et al. 1998). Workers in the painting sector are susceptible to diverse mixtures of organic solvents, toxic metals such as lead, zinc, chromium, cadmium, and several other potentially mutagenic compounds such as phthalic acid and chlorophenols.

In the painting industry, there are potential risks. It is useful to know about such risks and how they're being regulated in order not to expose people at work to risk (Table 1) (WorkSafe 2020).

Table 1 Possible hazards during painting

Work	Possible hazards
Painting occupation	Coloring pigments, acrylic, lead, cadmium, mercury, oil, cobalt, manganese, solvents (toluene, benzene, xylene, acetone, methanol, trichloroethylene, carbon tetrachloride, methanol, turpentine), mineral spirit, ammonia, formaldehyde, arsenic, barium, chromates, cadmium, alkyds, acrylics, titanium, zinc, uranium, vanadium

Reference: Zuskin et al. (2007)

Lead is a considered as concentrated toxin, so it can spread toxicity in any human organ and can cause significant chronic health consequences. Toxic lead contamination can be produced by scrubbing old paint. Spray paints also produce chemicals that are toxic. Occupational asthma can be caused by inhaling toxic vapors. Long-term exposure can cause brain damage, affect the reproductive organs, and cause permanent damage to the renal or liver. Chemical exposure can induce dermatitis. Wood dust may cause inflammation of the sinuses and throat, asthma, bronchitis, breathing difficulty, issues with the skin and indeed cancer. While using sanders associated with collection bags, workers can minimize dust it can have adequate breathing protection, such as a respirator, when work is performed.

Data mostly on risk during the work of painters, in particular the raw materials used and the solvents of heavy metals, and thus provide an incentive for the implementation of worker safety regulations (Manda and Mohamed-Katerere 2004). Safety tools have been developed by the researchers so that they can protect themselves as much as possible.

There are many tedious works performed by workers in the construction of buildings, although painting is still seen as a quite fascinating and creative work. Still as being creative it's also really hazardous for workers and painters are doing their job responsibly. Painters are desirable for certain work functions in residential and commercial buildings as these are considered as productive areas. In this way workers have to adopt to the environment so that they can endure physical conditions that are uncomfortable or even dangerous; they can operate at height also, and they cannot be distracted from the task at hand.

2 Personal Protective Equipment

A crucial part of keeping industrial painters protected is safety equipment. Several varieties of paints and other materials used by skilled painters are processed with toxic chemicals that, if the painters do not cover properly, may lead to health issues with time. In addition to professional painters, when working on any painting project, PPE can be used with paint and other varnishes (Essential Personal Protective Equipment 2019).

PPEs and Its Use:

Specific chemical-resistant equipment which are carried by professionals and certain other painters to protect them from the adverse effects of paint include personal protective equipment, or PPEs. These suits span the entire body and provide hoods, boots, and gloves, providing a protection from several forms of paint among painters and also the mists and fumes. To supply painters a fresh air, some PPEs even have respiratory protection. When working in confined areas which are not very well maintained, respirator mask is best advised. All painters must put on a pair of PPE, both expert and new, since they are often vulnerable to strong, nasty chemicals that may have permanent consequences (Essential Personal Protective Equipment 2019).

In risky jobs all painters should use safety with PPE. Mostly in manufacturing industries, PPE is given by the specific manufacturing industries to all workers, but still local painters who have not been linked to any factories and working independently are not provided and so they'll have to purchase their own PPE. The protective clothing is very easy to manufacture with innovative ideas by the equipment manufacturing firms and is also easily available in retail and online stores.

Benefits and Drawbacks of PPEs

Various types of paints have a variety of harmful chemicals. PPEs provide protection with it. A fresh air provided to painters that maintain their respiratory system and skin, healthy, and free of risk and furthermore prevents exposure to heavy paints fumes and other varnishes. The key disadvantages of such protective wear are that this can make difficulty in the movement of paint application and have the feeling of uneasiness, particularly for new painters. After working a long time with using PPE, they found it comfortable and considered it essential for their tedious job (Essential Personal Protective Equipment 2019).

To counter this circumstance, several forms of PPE were already produced. However, their efficiency and usefulness lack credibility. Usually, a current advancement for PPE is thus expected (Sawada et al. 2017).

Best Safety Equipment for Painting

Painters wear adequate personal safety gear available, including a breathing mask, lightweight overalls, protective gloves, and when sanding, eye protection (WorkSafe 2020). For keeping respiratory system clear by using of masks, respirators while sanding and painting. There are toxic vapors in certain colors, and drying can release hazardous chemicals into the environment which can affect the lungs and cause infection (The Home Depot 2020).

1. **Masks and Respirators**

Breathe safely when dealing with toxic substances by wearing the right respiratory health gear. During renovation and maintenance works, numerous tiny and pollen-free contaminants could get into airway, so it is essential to have the correct form of protection. Protect masks against the level of hazard, low toxicity dust. Protection

Table 2 Various types of respirators used during painting

Name	Description	Uses
Full face respirators and masks	Combination masks	• Provide protection against solid particles, gases, and vapors • Ideal for no-oil paint and solvent vapors
Dust respirators masks	Dust masks	• Protects against dust and solid particles
Gas and vapor—respirator masks	Gas and vapor respirator	• Protects against harmful gases and vapors • It is unable to protect from airborne particles
Odor—respirator masks	Latex paint and odor mask	• Protects against paint odors, latex paint, and pollens • Inhibit sanding dust, rust removal • Lightweight and comfortable
Fiberglass: respirator masks	Sanding and fiberglass respirator	• Particulate respirator that lessens exposure • Can be used for protection for the fiberglass • Lightweight and comfortable

Reference: The Home Depot (2020)

against toxic substances, vapors, and environmental contaminants is provided by respiratory protection (Table 2) (The Home Depot 2020).

Effectiveness and maintenance

To ensure efficient ventilation, amongst the most essential phases is to achieve a comfortable fit. Hazardous vapors would be free to get in there when the breathing mask is loose. So it is important to ensure that mouth and nose are protected by the product at all times. If the mask gets damaged structurally or mechanically, consider replacing a mask (The Home Depot 2020).

2. **Eyewear: safety goggles**

In the painting profession, eye injuries are the most common due to workplace dust and toxic fumes. A NIOSH study reports that workers in the U.S. have a substantial proportion of eye injuries every day irrespective to their jobs.

A study of Bureau of Labour Statistics (BLS) on workers who suffered eye injuries estimates that nearly three out of five did not use eye protection at the place of an accident. Most often, some workers felt that safety was not appropriate for the circumstance. Workers must use safety goggles to save their eyes from pollution and different chemicals since they are extremely resistant and protect away from potentially toxic elements (Protecting your Eyes at Work 2020).

Whenever operating with paint, use safety eyewear, eye goggles, or a face mask. It is particularly significant for both when painting or sanding.

3. **Coverall**

Coverall protection often prevents vulnerable exposed skin which has been easily affected due to paint exposure. The painters need strong protection against dust, sprays, and solvent splashes, as well as the need for apparel which can be required during bending, standing, crouching, and other various movements when dealing with rough surfaces, height, and ladder. In addition to protecting the skin, protective clothing also prohibits human contamination (Using the Right PPE for Painting Jobs 2020).

4. **Gloves**

Glove selection should not begin without an analysis of risk factor of that workplace. The glove for applications required for such sort of work has been seamless knit technology gloves (Occupational Health Safety 2020).

So, to cover the hands and skin, painters must always wear protective gloves. Leather or cloth gloves for sanding are appropriate. For handling paint thinners and certain other solvents, solvent-resistant gloves are essential. For water- and oil-based paint, impermeable gloves are safest.

5. **Hard hats**

In many circumstances, protective helmets are the basis for certain aspects of PPE. The painters must carry a protective hat from the very initial stages of his work and for the complete period of the work, as a result of a risk identification, and is accountable to use head protective gear in accordance with its intent (Jachowicz 2020).

A hard hat is a sensible precautionary measure when painters function at heights, as it will actually protect their heads if they fall.

6. **Fall protection belt**

Fall protection belts, generally referred to as industrial safety belts and harnesses, and are widely used in various hazardous works. It is intended to provide work strength and protection. In different sizes and designs, it can be adjusted as per the demand of various occupations. Various production companies that are associated with the manufacture of these products are used while moving activities (Industrial Safety Belts and Harnesses 2020).

To prevent users from falling, a safety equipment mechanism consisting of a single or double waist belt which can be fixed to a railing. For maximum safety, it also comes with a belt that is tied across the body and legs. In certain cases, scaffolding can also be used to avoid accidents from falling.

3 Conclusion

The study can be concluded by evaluation of various safety measures and their implementation at all levels is very crucial. Though protective equipment with advanced technology is available in the market, to enhance wearers comfort and ensure safety, the perception among uses for personal protection has to be motivated. The other prime factor is the cost of the PPE, which most of the workers could not afford and due to which, keep their lives at stake and work in unprotected environment. The high quality personal protective material, help, fine particulates, solvents, dust, and all other materials during work. The work efficiency of the workers can also be enhanced with maximum impact on productivity, if they are able to stay comfortable during the workday. Government has to take special entities for strict implementation of safety measures and use of PPE in all industries and the work sites where painters come in close contact with hazardous materials and chemicals leading to major chronic health issues.

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Chapter 12
Computational Assessment of Indian Excavation Workers' Posture and Biomechanical Analysis Using CATIA

Manoj T. Gajbhiye, Debamalya Banerjee, and Saurav Nandi

1 Introduction

A strong foundation plays a vital role in any construction work. The preliminary work is the erection of a column for the foundation, starting from the ground by excavating the soil crust to the construction of the house. In India, this dynamic, physically exhaustive, forceful and heavy weight-lifting work is carried out manually by both men and women who may be suffering from work-related musculoskeletal disorders (WRMSD).

Excavation is the process of removing soil by excavating the ground to lay down the foundation and erecting the column for construction work. This work is hazardous as well as dynamic in nature, which requires high physical effort and is carried out manually in India. These workers are exposed to different physical and environmental effects and are eventually exposed to work-related musculoskeletal disorders (WRMSD).

In India, excavation work is carried out manually and does not use machinery due to the unavailability of space for machinery, though the technology improved. The size of the column pit is varying as per the requirement, but the standard size of the column pit is 1.22 m × 1.22 m × 1.52 m, which is dug manually with the help of a pick-axe. This column pit takes 3–4 days for excavation by single workers with 8–10 working hours per day. The time of working and time of extraction depends on the type of soil, requirement of work and time to finish the task. During excavation work, the workers have to perform four tasks: (1) Excavation of soil crust with the help of

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pick-axe in which workers have to work with two postures as shown in Figs. 2a and 3a; (2) collection of excavated soil in the iron pan with the help of spade in which workers have to flexed forward >90°; (3) lifting of the iron pan from the ground to shoulder level and overhead and (4) throwing soil outside the pit or passing the iron to the outside worker when working in deep. The excavation work is a dynamic and repetitive work where the workers need to apply high force to loosen the soil and for lifting, throwing the excavated soil or passing the iron pan.

The assessment of such types of dynamic work is not possible without using a computer. Recently, the work processes were video-recorded and their analysis was carried out using computer software. Therefore, in this paper, the evaluation of Indian excavation workers' posture and biomechanical analysis of force/load on the spinal segment of L4/L5 is carried out using CATIA software.

2 Materials and Methods

2.1 Subjects and Data Collection

A total of 42 male workers were observed, interviewed and recorded from 16 different construction sites. Verbal permission from house owners, contractors and workers was sought first. The workers' data, pain or discomfort in body parts and other related problems were discussed and noted down.

A two-week study is carried out by visiting different construction sites. For collecting data, a simple questionnaire was framed, which consists of personal information, type of work activities, symptoms of WRMSD, other history of traumatic incidents etc. This survey helped in screening the frequency of WRMSD and other related aches or pain or discomfort in different body parts among the workers.

2.2 Review and Analysis of Working Posture and Biomechanics

Lynn McAtamney and E Nigel Corlett developed the RULA method for the upper body disorder analysis by considering biomechanical and postural load requirements. RULA is a quick assessment method that requires minimum tools like a clipboard, worksheet and pen. It evaluates the upper body, muscles efforts, exertion of force and repetitive movements responsible for muscle fatigue. Recently, the method was used in the precast industry (de Sousa Abreu and Neto 2017) and to evaluate the level of ergonomics risk of various tasks of construction work (Kulkarni and Devalkar 2018).

CATIA V5 is a CAD/CAM/CAE/PLE/3D surface modelling system software used for part designing, mechanical assemblies and generation of drawing. This software is equipped with human modelling and ergonomics analysis, like RULA analysis, push/pull, lifting and lowering analysis and biomechanical analysis. CATIA is widely used in a wide range of industries from conceptualization to manufacturing of complex designing development and simulation (Yogasara 2004).

The digital human model (DHM) of working postures of workers engaged in excavation work for the digging task was developed and analysis is carried out in CATIA V5 software using the RULA assessment tool and biomechanical analysis. Two postures are considered for this study and RULA score and biomechanical analysis of load on lumbar segment L4/L5 were carried out.

3 Results

The workers engaged in manual excavation work have mean (±SD) of age, height, weight, experience and BMI to be 40.69 (±9.39), 162.43 (±5.26), 61.11 (±5.72), 17.48 (±9.55) and 23.16 (±1.84), respectively. The duration of work depends on the work demand; the average working hours per day is 8–10 h with 1–1.5 h rest break.

During the study, all the workers reported some pain in the different body parts; among them, 47.62% of workers reported that they had pain or discomfort after working whose age is above 30 years and 21.43% of workers reported that they had pain in the morning whose age is between 45 and 50 years. The percentage of perceived pain or discomfort in the different body parts is shown in Fig. 1. From Fig. 1, it is revealed that the workers reported pain or discomfort in the lower back (83.33%), shoulder (83.33%), arms/hands (73.81%), wrist (40.48%), fingers/thumbs (30.95%), legs (26.19%), chest (21.43%), head (16.67%) and neck (7.14%).

No complaints about pain in the elbow, upper back, thigh/hip/buttock, knees and ankle/feet/toe. From the on-site observation and video-recorded observation, it was also found that 83.33% or more workers are working in awkward postures.

In this task, workers repetitively apply force to break the layer of the topsoil with the help of a pick-axe. All these working postures were observed and specifically selected awkward postures in the excavation work were video recorded. The most hazardous overworking postures and actions having the highest score in the RULA

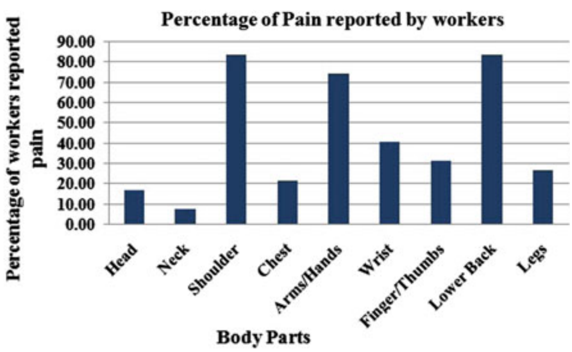
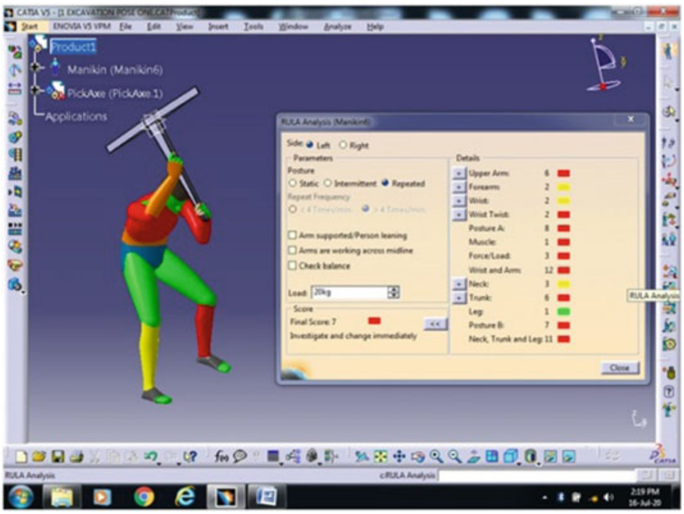


Fig. 1 Percentage of pain reported by workers

(a)

Fig. 2 **a** Real-time image of first body position. **b** RULA analysis of left side of the first position with worker holding pick-axe above the shoulder height. **c** RULA analysis of right side of the first position with worker holding pick-axe above the shoulder height



(b)

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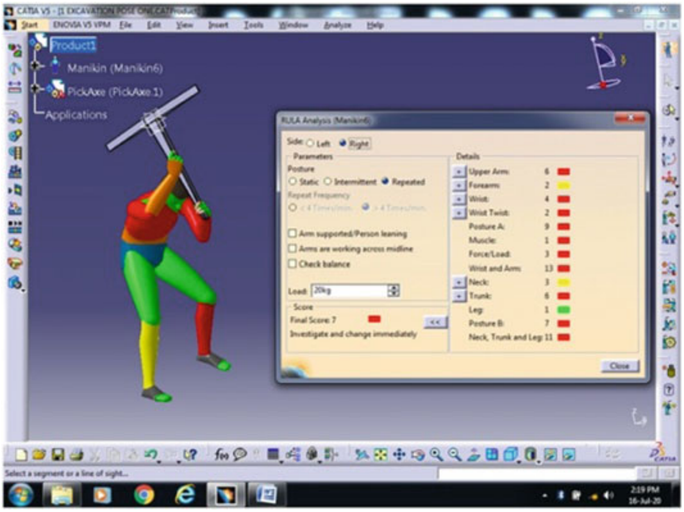

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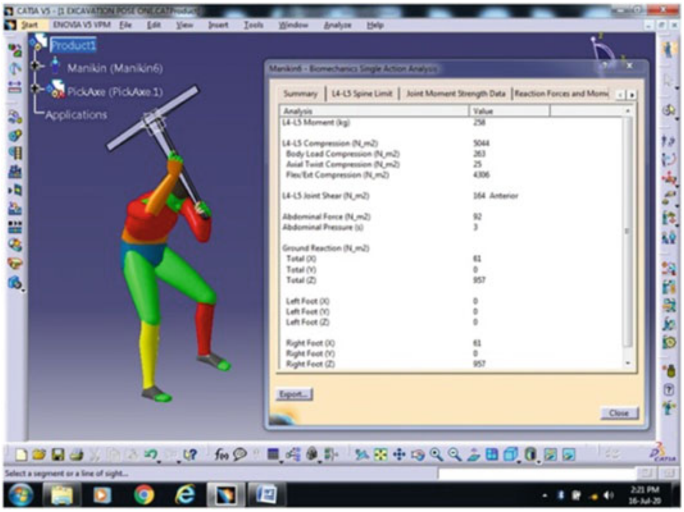

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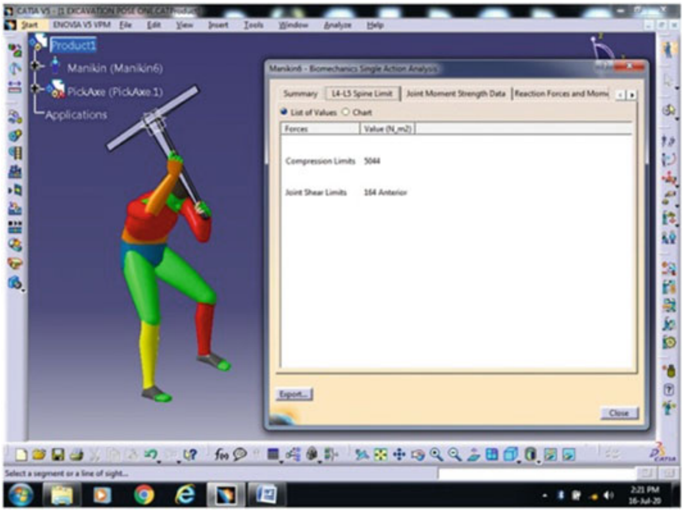

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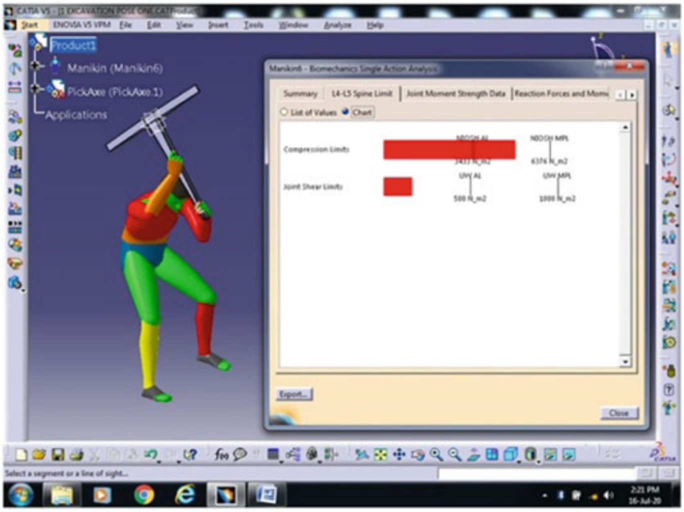
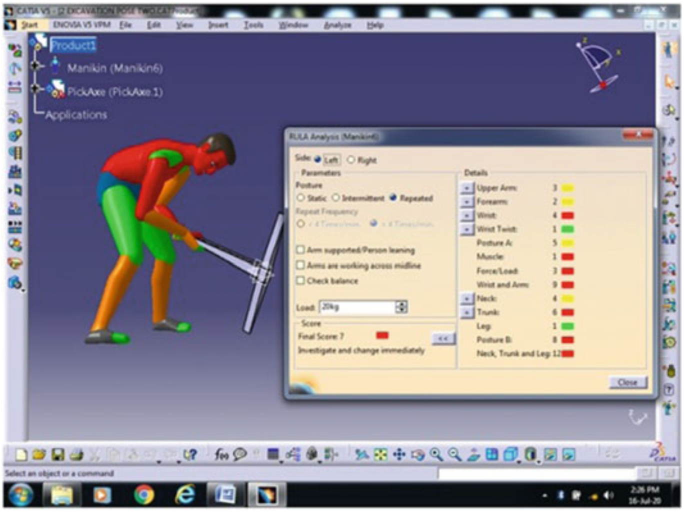


(f)

Fig. 2 (continued)

(a)

Fig. 3 **a** Real-time image of second body position. **b** RULA analysis of the left side of the second position with worker holding pick-axe below the shoulder height. **c** RULA analysis of the right side of the second position with worker holding pick-axe below the shoulder height. **d** Biomechanical analysis of the second position with worker holding pick-axe below the shoulder height. **e** Biomechanical analysis of the second position with worker holding pick-axe below the shoulder height. **f** Biomechanical analysis of the second position with worker holding pick-axe below the shoulder height



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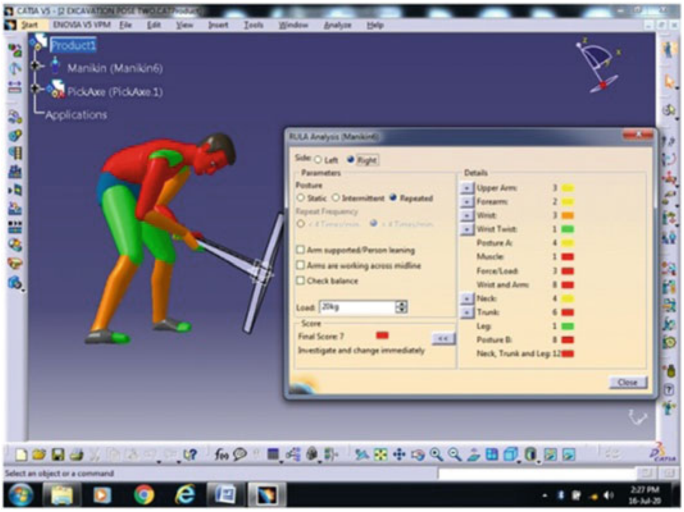

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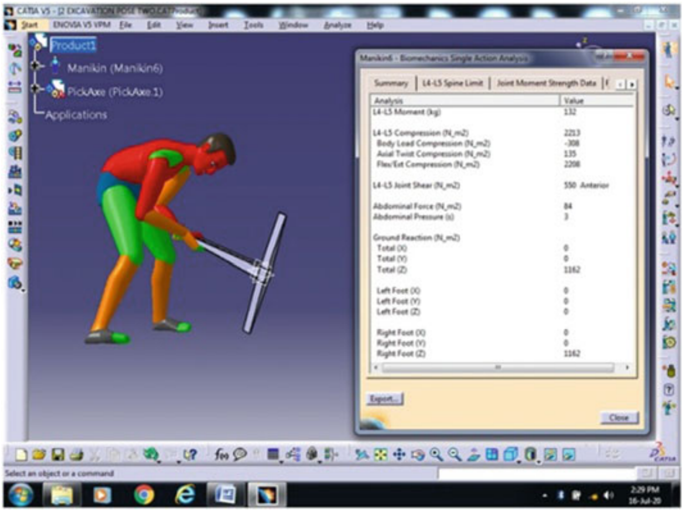

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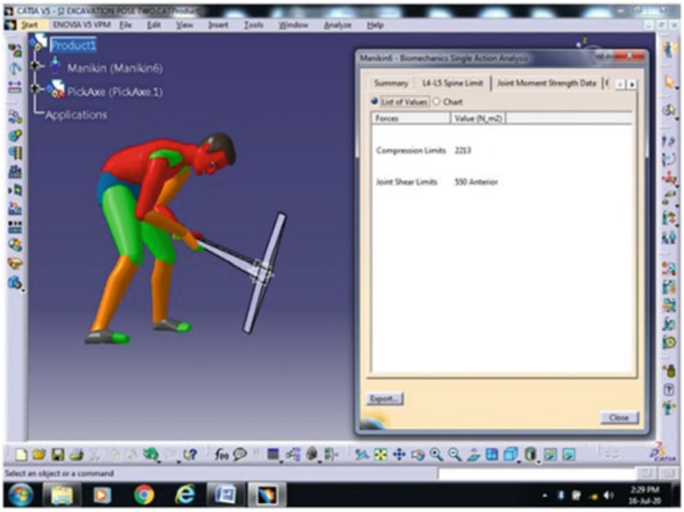

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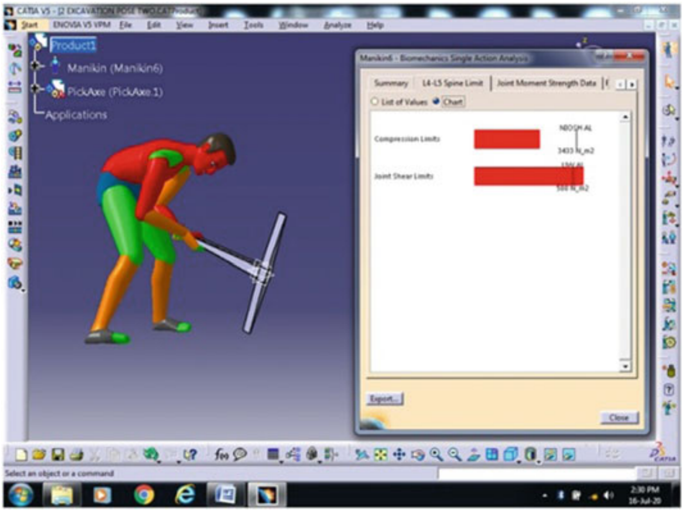


(f)

Fig. 3 (continued)

Table 1 Workers' responses for pain in different body parts

Body parts	No. of workers	% of workers
Head	7	16.67
Neck	3	7.14
Shoulder	35	83.33
Chest	9	21.43
Arms/hands	31	73.81
Wrist	17	40.48
Finger/thumbs	13	30.95
Lower back	35	83.33
Legs	11	26.19

worksheet assessment were chosen for critical analysis. The appropriate computer manikins are designed in CATIA V5. Moreover, the RULA and biomechanical analysis were carried out (Table 1).

Risk factors like a repetition of work, static muscle load, force, working postures and no break time are considered while designing the manikin to produce the final result. The manikin degree of freedom for all body parts has been set as per the standard rule of anthropometry of population and assigned green, yellow, orange and red. The green colour indicates "acceptable posture", yellow indicates "need further investigation and change", orange indicates "need further investigation and change soon" as well as red indicates "need investigation and changes immediately".

3.1 Analysis of First Body Position

During this task, workers' perform excavation work extending their shoulder, trunk extension, sometimes twisting of the trunk, both arms above the shoulder, radial deviation of the wrist when both arms are above the shoulder, ulnar deviation of the wrist when both arms are below the shoulder, legs are in flexion position (bent) at knees in between 30° and 60° and legs abduction. Figure 2a–f shows real image and manikin developed in CATIA with its RULA and biomechanical results.

For first body position, the RULA scores of repetitions of work, static muscle load, force, working postures and no rest time were observed. The final RULA scores for the left and the right side were found to be more than 7 (red). From Table 2, it is revealed that this needs investigation and required immediate change. RULA score shows that arms, wrist, shoulder, neck, trunk and legs are highly affected.

From Table 3, the maximum lumbar torque is 258 Nm. The compression force on L4/L5 at this position is 5044 N, which is above the maximum limit of 3400 N recommended by NIOSH (Hlavkova et al. 2016; Afshari et al. 2018; Arjmand et al. 2015). The compression of L4/L5 is not appropriate and need to be reduced (Hlavkova

Table 2 RULA scores for first, second and new proposed conceptual body position

Working postures	Left			Right		
	Wrist/arms	Neck/trunk/legs	Total score	Wrist/arms	Neck/trunk/legs	Total score
First body position	12	11	>7	13	11	>7
Second body position	9	12	>7	8	12	>7
Proposed conceptual body position	5	4	5	5	4	5

Table 3 Biomechanical analysis on the spinal segment of L4/L5 of first, second and proposed conceptual body position

Parameters	Action limit		
	First body position	Second body position	Proposed conceptual body position
Torque (Nm)	258	132	38
Compression (N)	5044	2213	1131
Compression on body load (N)	263	−308	490
Axial twist compression (N)	25	135	0
Flexion/extension compression (N)	4306	2208	631
Joint shear load (N/m^2)	164 (Anterior)	550 (Anterior)	82 (Posterior)
Force on abdomen (N)	92	84	0
Pressure on abdomen (N/m^2)	3	3	0

et al. 2016; Afshari et al. 2018; Arjmand et al. 2015). The joint shear load of L4/L5 at this position is 164 N/m^2, which is below the maximum action limit of 500 N/m^2 and is appropriate (Hlavkova et al. 2016; Afshari et al. 2018; Arjmand et al. 2015). In this posture, 92 N force is applied on the abdomen with a pressure of 3 N/m^2. The detailed biomechanical result is presented in Table 3.

3.2 Analysis of Second Body Position

While doing excavation work, the worker's second position is shown in Fig. 3a–f. In this position, the tip of the pick-axe barge into the soil. Workers then need to apply force to remove the pick-axe; with that the layer of the soil is also removed. The workers' hazardous postures during this task are forward bending (flexion) of the trunk more than 90° at lumbar, arms below the shoulder height, twisting of trunk every so often, radial and ulnar deviation of the wrist, legs are in flexion position (bent) at knees between 30° and 60° and abduction position (Fig. 3a–f).

For this position, the final RULA (Table 2) score for the left and right sides was found to be more than 7 (red) which revealed that it needs investigation and required immediate change. The RULA score shows that upper arms, wrist, neck, lumbar and legs are deeply affected.

From Table 3, the maximum lumbar torque is 132 Nm when the worker is in this position. The compression at L4/L5 was found to be 2213 N which is under the maximum action limit of 3400 N. However, the joint shear load of L4/L5 at this position is 550, which is found to be above the maximum action limit of 500 N/m^2. It is not appropriate and not acceptable. In this position, 84 N force was applied on the abdomen with 3 N/m^2 pressure. The detailed biomechanical result is presented in Table 3.

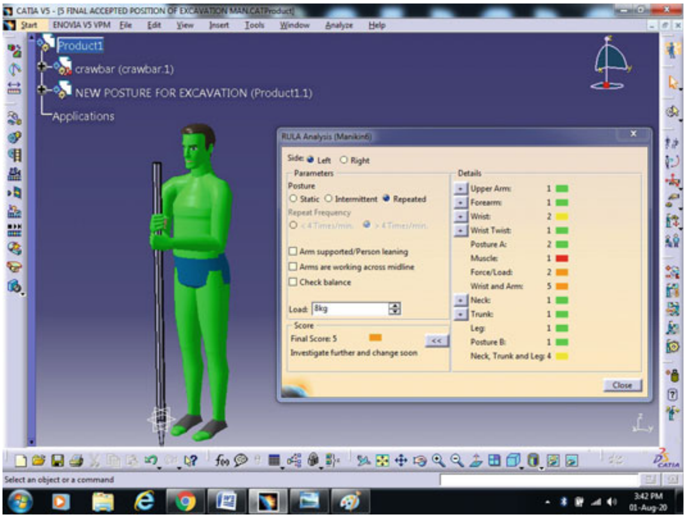
3.3 Design Concept for the Proposed Conceptual Working Posture

In conceptual design, the pick-axe is replaced by a crowbar for excavating the task. The weight of a crowbar ranges from 3 to 8 kg and is used for excavation. By using a crowbar, the workers can work in the posture shown in Fig. 4a–e. The RULA score for this working posture was derived and the score obtained for this posture for both right and left sides is found to be 5 (Table 2). At the same time, all the body parts are not exposed to any hazardous working posture. Also, the effort required for doing excavation work in this posture seems low.

From Table 3, the maximum lumbar torque at L4/L5 was found to be 38 Nm with L4/L5 compression of 1131 N which is less and is under the maximum action limit of 3400 N. Also, the joint shear at L4/L5 is 82 N/m^2, which is also below the maximum permissible action limit. The force and pressure on the abdomen were also found to be zero. The use of crowbars was found to be more feasible than the use of a pick-axe for the excavation work to work in the erect position.

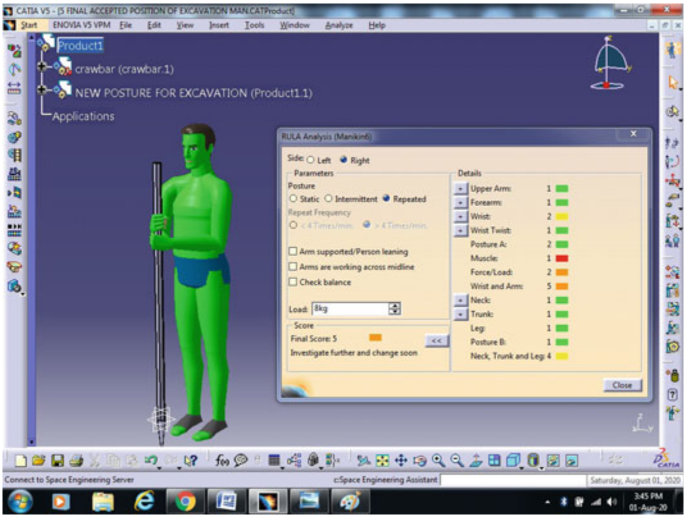
4 Discussion

CATIA V5 software was used for developing the real-life working posture of the excavation workers to find the effect of working in an awkward posture, forceful exertion, repetitive work, an overload of muscles on the different body parts of the workers with the effect of force/load on the spine at L4/L5 segment. The use of CATIA V5 software provides many features to create the working posture and carry out analysis of work. There are many other computational methods available



(a)

Fig. 4 **a** RULA score of the left side of the proposed working posture using a crowbar. **b** RULA score of the right side of the proposed working posture using a crowbar. **c** Biomechanical analysis of the proposed working posture using a crowbar. **d** Biomechanical analysis of the proposed working posture using a crowbar. **e** Biomechanical analysis of the proposed working posture using a crowbar



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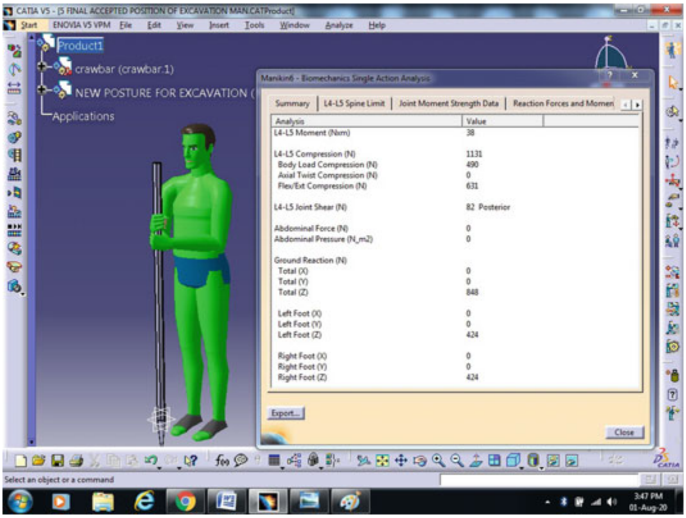

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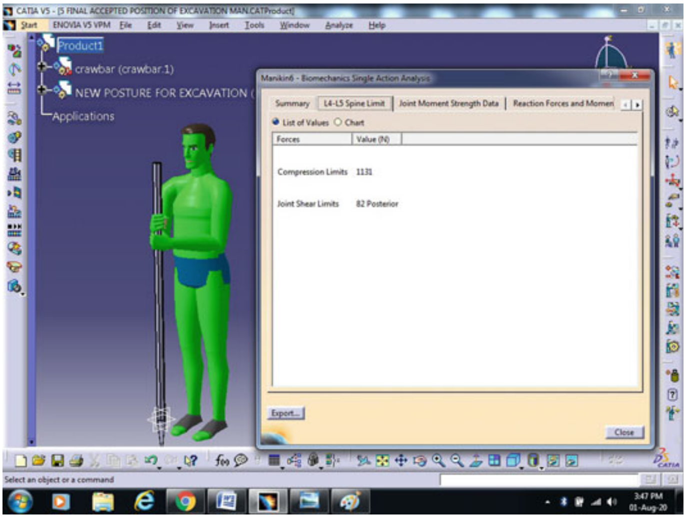

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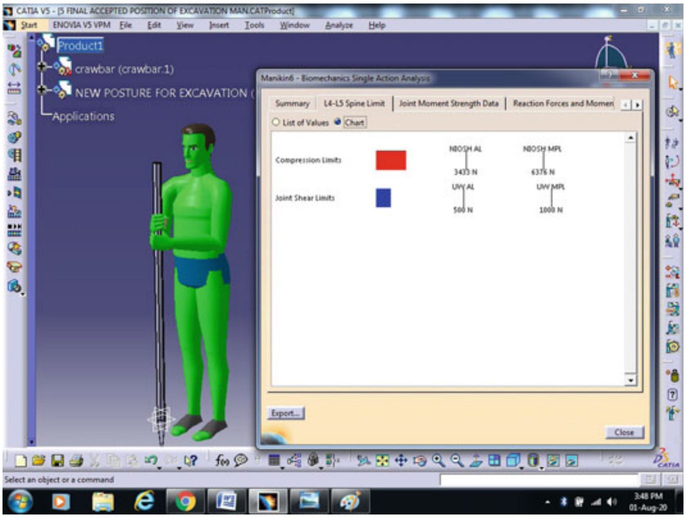

(e)

Fig. 4 (continued)

(Rahman 2011; Sanchez-Lite et al. 2013; Hashim et al. 2014; Pavlovic-Veselinovic et al. 2016) that can be used.

In this analysis, for the first position, the RULA score for both postures was found above the score of 7, which highlighted that it needs immediate corrections. The biomechanical analysis also shows that when the arms are above the shoulder level with heavyweight material and in the flexion position, the compression at L4/L5 is high.

For the second working position, the biomechanical analysis shows that compression at L4/L5 is low but joint shear load at L4/L5 is high and also bending forward at an angle of more than 90° is not acceptable, and as the flexion position increases the load on L4/L5 increases and will vary with body weight (Hlavkova et al. 2016). Many researchers have also started working in the construction area and highlighted the issues related to physical exposure among the construction workers (Antwi-Afari et al. 2017; Chen et al. 2017; Valero et al. 2016).

The recommended working posture with the proposed tool will help to minimize the force/load on different body parts and at L4/L5 of the spinal cord. Also, the workers are not required to bend forward and apply force only with arms only. RULA score shows that there is no adverse effect on body parts. From the biomechanical analysis, the compression and shear force on L4/L5 is under the maximum action limit suggested by NIOSH.

5 Conclusion

The RULA score shows that both the positions in which excavation work is carried out by the workers are at high risk. The biomechanical analysis revealed that the present working posture applies a high load on L4/L5 of the spinal cord. The suggested working posture with the working tool will minimize the effect of working in awkward posture and also minimizes the compressive as well as the shear load at L4/L5 lumbar segments of the spinal cord, which leads to the development of WRMSD in excavation workers.

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Chapter 13
Design and Development of a Seat Simulator to Study the Body Mass Supported on Seat Pan and Backrest

S. Thokchom, K. N. Dewangan, and A. Pal

1 Introduction

The distribution of mass on seat changes with sitting positions (Bush and Hubbard 2007). A male sits in such a way that the pelvis rotated posteriorly, their hip joints and centre of mass are posterior to the seat pivot point while for females the pelvis rotates anteriorly and also their hip joints and centre of mass are positioned anterior to the chair pivot point. When a backrest is provided they sat with their focal point of mass nearer to the centre of the seat pan (Dunk and Callaghan 2005). Different design recommendations are suggested for different gender and race. Therefore, it is necessary to match the anthropometry of the target user (Manjrekar and Parkinson 2011). The quantification of 3D weight dispersal on the seat could be valuable for the ergo-design of seats for refining sitting discomfort and comfort (Nag et al. 2008). The most referenced aspect for ergonomic design vehicles is the biomechanical study of driver posture (Andreoni et al. 2002).

The posture of a driver is affected by the task and workplace, and thus impose a load on the structures of the body (Mehta et al. 2008). The posture of a tractor driver is different from the driver of on-road vehicles. The tractor drivers have to look back to see the task performed with an implement or a machine mounted on the rear of the tractor. The posture of the tractor drivers is different for an implement or machine mounted on the front of a tractor. Several problems for physical health occur when prolonged seated working is involved, so it raises the risk of distress musculoskeletal conditions in the back, neck, shoulders, arms, and legs (Naqvi et al. 1994). The majority of the body mass is positioned on the supporting area of the ischial tuberosities of the pelvis and the tissues in proximity. Postural factors, personal factors (anthropometric variables), as well as seat design factors are the parameters that affect tissue compression and interface pressure on the seat pan (Vos et al. 2006).

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The major components of a seat are the armrest, seat pan, and backrest. The seat pan, backrest, and armrest support the upper body as well as a part of the upper leg, while a part of the upper leg and the lower leg is relaxed on the ground surface (Mehta et al. 2008).

The seat plays an important role in providing comfort to the driver (Mehta et al. 2008). Sitting comfort and discomfort are determined by a subjective and objective method such as posture analysis, pressure measurements and electromyography (EMG) at the seat operator interface. Besides subjective feeling incorporation of pressure measurements would be valuable (De Looze et al. 2003). A combination of physiological and psychological processes, body posture related to muscle fatigue and total time spent on task can result in discomfort, and both objective and subjective assessment should be done to evaluate seating discomfort (Mehta and Tewari 2000).

The mass supported on the seat pan and backrest play a vital role in vibration transmissibility. Body mass supported as well as pressure distribution on backrest and seat pan are affected when back support inclines from horizontal, and pressure at buttocks increases as the inclination of back support decreases. The higher the inclination angle, the higher is the back support pressure. Mean pressure increases linearly as the BMI increases, whereas there was no relation between the maximum pressure and BMI (Hostens et al. 2001). Compared to upright unsupported sitting mass supported by a seat at back inclines was 10–12% less. Compared to unsupported back mass on feet support varied narrowly at upright supported back. Since the body mass supported at seat pan repetitively reduced by 12% at seat height 68 cm, this height was optimized. When the armrest is present the load on feet was 18% greater, indicating that when the armrest was absent a portion of upper leg weight fell on the seat pan. The study confirms that the backrest and armrest have a combined effect in decreasing the weight distributed at the seat (Nag et al. 2008).

Furthermore, the average buttock–seat interface force and the contact part are directly affected by the body mass of the seated body which is mainly reliant on visco-elastic properties and contouring of the seat (Rakheja et al. 2020). The use of a proper cushion made from proper material help relieve discomfort and provide desirable comfort. Cushion contact part, cushion front part/force, and seatback contact area could be modelled by subject anthropometry. For cushion contact area and cushion front contact area, body mass and hip circumference were the best indicators, whereas for seatback contact area and seatback upper contact area, body mass and bi-deltoid breadth were the best parameters (Paul et al. 2012).

Persons may respond in a different way to numerous chair designs and the reasons that affect these sitting behaviours are not well understood. A study on quantification of the mass distribution on the seat comprising the seat pan, backrest, armrest, and footrest is lacking. Thus, a seat simulator designed and developed to measure body mass distribution for different seating configurations was studied.

2 Design and Calibration of Seat Simulator

2.1 Design and Development of Seat Simulator

Anthropometric parameters of the subjects in Mehta et al. (2008) were considered for designing a seat simulator. The anthropometric parameter is sitting acromion height (5th percentile), sitting hip breadth (95th percentile), buttock popliteal length (5th percentile), interscye breadth (5th and 95th percentile) and popliteal depth (5th percentile), for the design of seat backrest height, seat pan width, seat pan length, seat backrest width, and seat height, respectively. Dimensions used in the simulation of the seat are seat height (367 mm), seat pan width (364 mm), seat pan length (382 mm), backrest width (364 mm), and seat backrest height (492 cm). The seat simulator was designed to change seat pan inclination from 5° to 20° and backrest reclination from 100° to 120°. The seat was designed using AutoCAD software to eliminate any type of unwanted error like misplacement of sensors while fabricating the simulator.

The designed seat simulator was fabricated using angle iron and plywood. It consists of a seat pan, backrest, and seat frame. Seat height was fixed in the entire experiment to avoid adjusting the seat height. The effect of different anthropometric dimensions, i.e., stature on seat height is taken care of by providing footrest. A footrest was provided to support feet. The footrest was fabricated in such a way that it could be raised and lowered down and moved forward and backward. The height of the footrest was changed to accommodate subjects of different anthropometric dimensions. The reclination of the backrest was controlled by a metal slab. One end of the metal slab was fixed at the frame of the seat pan and another end is attached to the backrest frame. Five holes were drilled on the metal slab and the frame of the backrest in such a way that the combination of each hole could provide backrest reclination angle of 100°, 105°, 110°, 115°, and 120°. For seat pan angle, wooden blocks of different heights were provided between the seat frame and seat pan to obtain a seat pan angle of 5°, 10°, 15°, and 20°. All the angles of the seat pan and backrest recline were predetermined to obtain the proper setting of the angles. A steering wheel was provided to support the hand of the driver. Figure 1 shows the developed seat simulator.

Four strain gauge-based load cells of 20 kg capacity were mounted on the seat pan. Thus, the seat pan could carry a load of 80 kg. Similarly, four load cells were mounted on the backrest so that it could support 80 kg. Figure 2 shows the mounting of the load cells on the seat pan and backrest.

2.2 Calibration of Seat Simulator

All the load cells were calibrated individually using known mass after mounting load cells on the fabricated seat simulator. The load cells were of cantilever type;

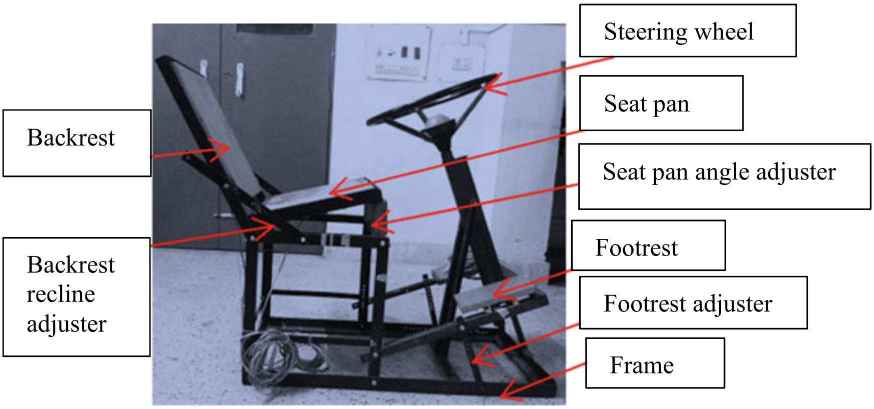
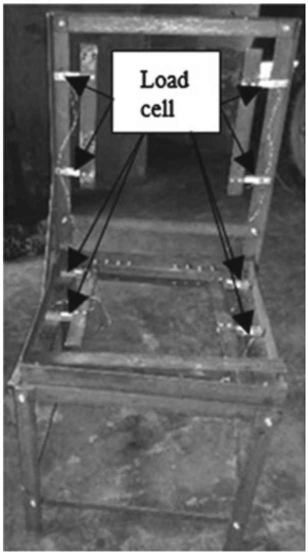


Fig. 1 Developed seat simulator

Fig. 2 Mounting of the load cells on fabricated seat simulator



therefore, a platform was provided at the end of the load cells for calibration. A known mass was put on the platform and data was recorded using a data logger (Data taker DT800) for both loading and unloading of the mass. Calibration graphs of all the load cells were plotted for further use in the experiments. All the load cells on the seat pan and backrest were connected parallel separately and it was connected to the data logger.

A calibration equation was developed for each load cell. Figure 3 shows calibration equations developed for all the load cells.

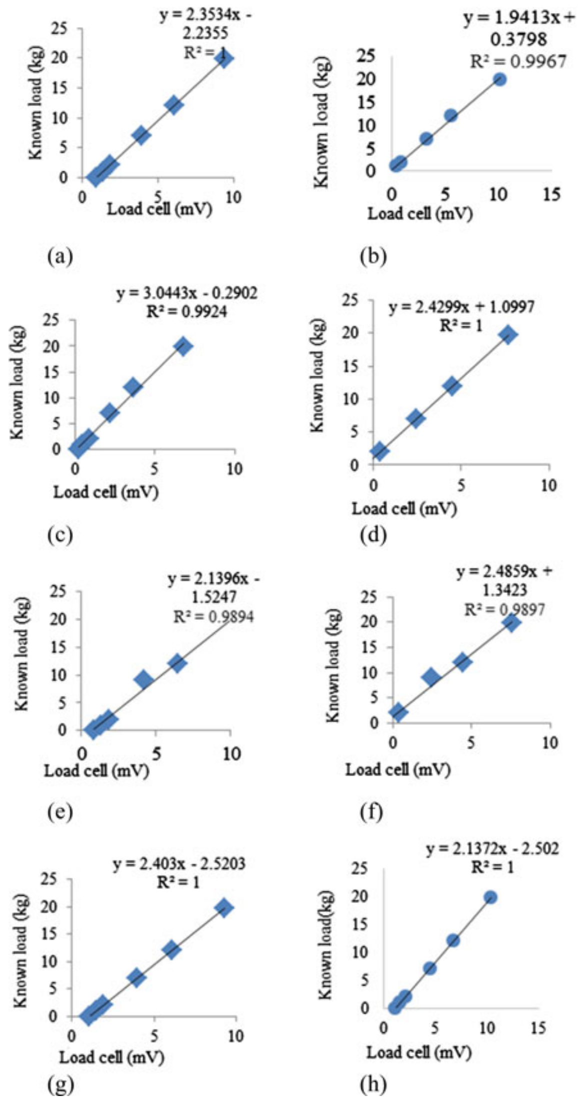


Fig. 3 Calibration of load cells: **a** backrest left down, **b** backrest left up, **c** backrest right down, **d** backrest right up, **e** seat pan left down, **f** seat pan left up, **g** seat pan right down and **h** seat pan right up

3 Verification of Simulated Seat

3.1 Selection of Subject

Six male subjects (age: 23–25 years) were selected randomly. All the subjects were free from a physical disability. Consent from the subjects was also obtained. The anthropometric dimensions of the volunteers were measured using a measuring tape and an anthropometric scale.

3.2 Experiments

Anthropometric dimensions, namely the neck circumference, waist circumference, hip circumference, stature, and body mass, were measured for each subject using a measuring tape and weighing scale. Hip circumference was measured around the pelvic bones and waist circumference around the navel.

Subjects were requested to sit on the seat pan with the back supported on the backrest and knees bend at 120° where the feet are at full contact with the footrest. For every backrest recline the seat pan changes in four-set. After every two trials the seat arrangement was changed (seat pan slope was changed as 5°, 10°, 15°, and 20°). Measurements were taken from each subject for 20 sets of sitting trials of about two hours, with each sitting trial was about 4 min duration including rest. After 2 min of quiet sitting, the signals were sampled twice for the duration of 10 s each at a sampling frequency of 10 Hz. Figure 4 shows the measurement of body mass supported on the seat pan and backrest of a male subject.

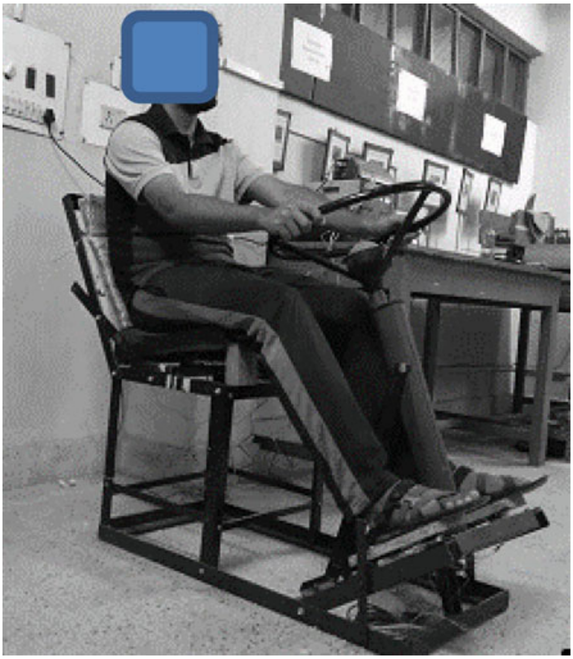


Fig. 4 Measurement of mass supported on the seat pan and backrest of a male subject

3.3 Data Analysis

Data recorded in the data logger was extracted in an Excel spreadsheet. Using calibration equations, body mass supported on the seat pan, backrest and footrest were determined for all the 20 combinations of seat pan angle and backrest recline. Percentage of body mass distributed on the seat pan, backrest, and footrest for all the combinations of seat configuration was also calculated. Total body mass determined through a seat simulator was compared with that measured using a weighing scale.

3.4 Results and Discussion

The mean body mass of the subject was found to be 63.03 kg with a 2.73 standard deviation and range 60–70 kg. The mean stature of the subject was 161.5 cm with a 3.39 standard deviation and range 158–167 cm. It was assumed that the body mass supported on the steering wheel is one kg throughout the experiment. Table 1 shows the body mass supported on the footrest, backrest, and seat pan. Figure 5 shows the percentage of body mass distributed on the footrest, backrest, and seat pan. Percentage of body mass distributed on seat pan for all the combination of seat configuration ranged from 50 to 64%, while on backrest and footrest it ranges from 20 to 30% and 11 to 20%, respectively. The authors of Dewangan et al. (2013) reported that about 75% of body mass is supported by the seat pan and backrest on a straight seat pan and upright backrest. It was also observed that mass distribution on the seat pan decreased as the backrest recline increased. One of the reasons for the change in body mass distribution could be more mass is transferred on the backrest when the backrest reclined. The percentage distribution on the seat pan and backrest is mainly reliant on the sitting posture of the subject (4). It is found that the body mass on the seat throughout the experiment was 99.21% (mean) which shows the different load cells measured body mass accurately at various locations. It could be deduced that the developed simulator is accurate to the level of 99.21%.

Table 1 Mass distribution on supported on the seat pan, backrest, and footrest

S. no	Combination of seat pan angle and backrest recline	Body mass supports on seat pan (kg)	Body mass supports on backrest (kg)	Body mass supports on footrest (kg)	Total body mass on the seat (kg)	Percentage of body mass on the seat (%)
1	sp5br100	36.74	12.05	11.12	61.22	97.12
2	sp5br105	33.61	13.62	11.12	62.37	98.95
3	sp5br110	33.74	15.10	11.18	62.10	98.52
4	sp5br115	30.97	16.46	12.25	62.07	98.48
5	sp5br120	30.51	17.56	12.14	62.69	99.46
6	sp10br100	37.42	12.47	9.22	62.45	99.09
7	sp10br105	36.38	13.47	9.94	62.33	98.89
8	sp10br110	35.71	14.66	9.27	62.05	98.45
9	sp10br115	33.89	16.23	9.98	62.22	98.71
10	sp10br120	32.51	17.44	10.15	62.28	98.82
11	sp15br100	39.38	13.73	6.89	62.31	98.85
12	sp15br105	37.09	14.35	8.52	63.52	100.08
13	sp15br110	36.45	15.89	7.66	61.87	98.15
14	sp15br115	34.17	17.13	8.50	62.33	98.89
15	sp15br120	33.25	18.20	8.76	62.84	99.70
16	sp20br100	38.23	14.83	7.20	64.40	102.18
17	sp20br105	37.65	15.26	7.46	64.51	102.35
18	sp20br110	36.07	16.20	7.67	61.95	98.28
19	sp20br115	34.80	17.75	7.34	62.95	99.87
20	sp20br120	33.27	18.88	7.32	62.17	98.64

* sp-seat pan angle°, br-backrest recline°

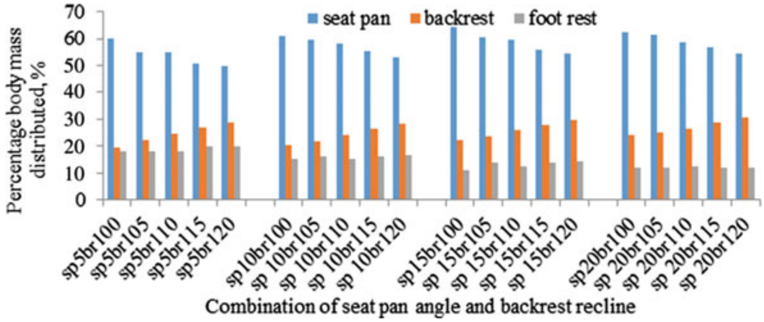


Fig. 5 Percentage of body mass distributed on the seat pan, backrest, and footrest

4 Conclusion

The following can be concluded from the study:

1. The developed seat simulator worked satisfactorily for all combinations of seat pan and backrest.
2. It is verified that the simulated seat gives 99.21% accurate data.
3. The developed simulator can be used for further study.

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Chapter 14
Designing of Apparel for Arm-Fractured Women

Irfana Qiyamuddin Siddiqui and Sunita Namdeorao Kale

1 Introduction

Clothing is one of the basic necessities of mankind. Clothing is a complex but fascinating part of an individual's life (Tuteja and Nigam 2017). Proper clothing fosters an overall development of the person (Kefgen and Phyllis 1971). The influence that clothing can have on the life of someone with a physical disability is significant (Esmail et al. 2018). Because adjusting physically to the disability requires a great deal of time and energy, clothing often becomes a minor problem that one has to tolerate and accept (Brown 1969). Clothing can hide physical defects and give aesthetic pleasure to the wearer through its special features (Kishore et al. 2010). Most people with physical disabilities want clothing that is attractive in appearance, comfortable, functional and easy to manage, safe and easy to care for (Brown 1993; Suri 2016; Textile Chain 2020).

It has been observed that arm-fractured women face a lot of problems in wearing of clothes during the stage of plaster on their hands and exiting garments are not at all suitable for dressing up comfortably. Women are restless because no proper clothing is available for covering the body, lack of attention of family members toward disabled women because of their busy life schedule and lack of availability of apparels for special needs in the market. Functional clothing is different from normal wear, but disabled ones do not want to look different from other people with this functional clothing. Therefore, they want a simple and normal appearance with functional clothes (Sharawat and Hooda 2018). Alteration of existing apparels is time-consuming and many of them may not suit disabled persons much. Frustration occurs to them while wearing the clothes. Under such circumstances, disabled persons undergo mental stress and lose confidence and require more time for health recovery. Apparels need to be designed for arm-fractured women suitable for wearing

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next to the skin comfortably and independently to eliminate the pain and frustration of dressing. The study was undertaken to design the everyday wear, i.e., Punjabi Kameez for the women having a fractured arm with plaster on it and to assess its suitability to the subjects.

2 Methodology

This research work comprises a survey and experimental designing of apparels for arm-fractured women during the stage of plaster on their arms.

2.1 Survey

A survey was conducted among 75 arm-fractured women from various orthopedic and civil hospitals of Parbhani district of Marathwada region of Maharashtra State, India. Information about problems faced by arm-fractured women themselves in dressing and also the problems perceived by their caretakers was collected with the prepared questionnaire through personal talk and discussion. The collected information was tabulated and explained in percentages.

2.2 Designing of Punjabi Kameez

2.2.1 Selection of Women

A purposive sample of 30 arm-fractured women with plaster on their arms was selected for the study.

2.2.2 Selection of the Style of Garment

Punjabi Kameez was the garment selected for sketching, designing, and construction because Punjabi dress was being used daily by the respondents.

2.2.3 Anthropometric Measurement

Individual body measurements of 30 selected arm-fractured women were taken for Punjabi Kameez such as full length of Kameez, length of sleeve, outside and inside of arm, armhole, shoulder, around chest and waist. Average basic body measurements were considered. Additional amount of stitching ease and wearing ease was added in the average measurement of Punjabi Kameez at shoulder +1.5 in., chest +2 in., waist +2 in. and in arm hole +2 in., for providing enough room for minimizing the problems of strain caused in wearing of Punjabi Kameez.

2.2.4 Selection of Fabric

Pure cotton poplin fabric of plain weave of fine quality in soft pastel colors of sky blue, pink was selected for the stitching of Punjabi Kameez.

2.2.5 Selection of Fasteners

Different types of fasteners were selected, such as Velcro fastener, zipper coil and big size press buttons to evaluate the type of fasteners easy for fastening using a healthy hand without the help of others.

2.2.6 Preparation of Fabric

The selected poplin cloth material was washed to remove starch, made soft and pressed.

2.2.7 Sketching and Designing of Punjabi Kameez

While making garments, detail orientation and minor to major points need to be considered, like allowance for free movements, using breathable fabric and fasteners that are easily handled (Textile Chain 2020).

Two different designs of Punjabi Kameez were planned and sketched:

Design I: Punjabi Kameez with set-in sleeves.

Design II: Punjabi Kameez with Kimono sleeve.

2.2.8 Design I

A Punjabi Kameez was designed with full length up to the knee (40 in.) and front opening using fastener arrangement for easy put on and take out, with large armhole, gent's roll collar for the protection from the trouble caused by the cord of plastered hand hanging around the neck, and full-length sleeves (22 in.) for the safety from external agents and for the plastered hand. Flap pocket was planned at waist level for keeping spectacles, mobile and handkerchief. Openings were designed on the sleeve for plastered hand in three different directions. The designs were as follows:

Design I (A): At the fold line of the sleeve, an opening was provided from shoulder to wrist.

Design I (B): Sleeve opening was provided from neck, collar bone level to the wrist.

Design I (C): Underside of the arm, the sleeve opening was designed up to in the side seam of Kameez.

Design I

2.2.9 Design II

A Punjabi Kameez with a Kimono sleeve was designed. The length of the designed Kameez was above the knee up to thigh level, gent's Nehru shirt style narrow collar was designed for the protection from the trouble caused by the cord of plastered hand hanging around the neck, front bodies provided placket opening of 15 in. in length with fastener arrangement for easy put on and take out and full-length sleeve (22 in.) of large Kimono style for easy sliding of plastered hand without rising and lowering it. On collar bone, a loop of fabric was provided for tieing of a handkerchief for frequent use and a pocket was stitched on waist level for keeping spectacles and mobile. For plastered hand sleeve opening was designed in three different directions. The designs were as follows:

Design II (A): Outside of arm sleeve opening was provided from shoulder to wrist.

Design II (B): Sleeve opening was provided from neck collar bone level to wrist.

Design II (C): Inside of arm sleeve opening was designed to seam line.

Design II

2.2.10 Preparation of Paper Draft

According to measurements, paper drafts of Punjabi Kameez were prepared, transferred on fabrics, and fabrics were then cut and stitched.

2.2.11 Stitching of Developed Design of Kameez

Three Punjabi Kameez were stitched in each direction of sleeve opening (design of sleeve opening I, II and III) and Velcro fastener, zipper fastener and big size press button fastener were stitched and fixed on each design of sleeve separately to know which type of fasteners is easy for handling with a healthy hand without the assistance of others.

2.2.12 Testing of Developed Design of Kameez for Acceptability by Wear Trials

Designed Punjabi Kameez was provided to the selected 30 women for wear trials for three consecutive days. Responses of the wearers for different parameters were studied such as the design of Kameez, comfort, ease in putting on and taking out, the texture of the fabric, seam finishes, direction of sleeve opening and similarly which type of fastener was easy to handle without any assistance of other person with minimum strain to the body.

2.2.13 Rating Scale for Assessment

A three-point rating scale was used for the assessment of Punjabi Kameez and was rated accordingly.

Highly suitable/acceptable—3.
Suitable/acceptable—2.
Somewhat suitable/acceptable—1.

3 Findings

Table 1 depicts problems reported by arm-fractured women in wearing upper body garments, i.e., Kameez. Cent percent arm-fractured women stated problems like assistance needed for dressing and it was very difficult and painful. Common styles of the garment were not comfortable due to plaster on hands, doffing of the garment, inability to stretch and pull up the elastic band of the lower garment to waist level with

Table 1 Problems reported by arm-fractured women in wearing of clothes (N = 75)

Problems	Percentage
Assistance needed for dressing	75(100)
Common styles of garment are not comfortable due to plaster to hand	75(100)
Common styles of garment need to have cut in seams	75(100)
Doffing of garments	75(100)
The elastic band is unable to stretch and pull up to waist level and find difficulty in the lower garments	75(100)
Knowledge about clothing for special needs is not available in the market	75(100)
Specially designed garments will be preferred	75(100)
Even after tear and cut, the garments are not suitable and comfortable	72(96.00)
Problems in one-piece garment	
Due to oversize of the garment, it bunches, so tucking at the back, waist and lower side of the leg is a problem	68(90.66)
It raises upward while sleeping and seating position	68(90.66
Fasteners of gown not appropriate to fasten hook and eye, button to put in buttonhole	62(84.00)
Seam slippage in adjusting the gown	55(73.33)
Threads of seam of gown get unraveled and produce etching sensation to the body	55(73.33)
Due to short sleeve in the gown, feel of unsafe and insecurity from external agents	42(56.66)
Due to the long and loose-fitting of the gown at the chest, waist and hip, gown rolled and wrapped around the body	42(56.66)
For other activities, to hold and manage gown with one healthy hand is difficult	33(44.00)
Garments with zipper are unmanageable as it finds difficult to pull up by other healthy hand	30(40.00)

Figures in parenthesis indicate percentages a healthy hand, developed pain, knowledge about clothing for special needs was not available in the market. Special and specifically designed garments will be preferred by the arm-fractured persons. A higher percentage of 96 women expressed their problems for common styles of garment needed to have cut in seams, even after cut garments were not suitable and comfortable to wear and developed pain. Generally, one-piece garment like gown was used by the hand disabled women. Regarding the one-piece garment (gown) 90.66% of arm-fractured women expressed various problems faced in wearing the gown, such as due to oversized garment it bunches, tucking at back, waist and lower side of the leg got raised upward while sleeping and seating. The problem of seam slippage in adjusting the garment, threads of seam of gown got raveled and produced etching sensation to the body. Fasteners were not appropriate to fasten as hook and eye; buttoning put in buttonhole was reported by the women in the range of 73.33–84.00%. Arm-fractured women reported (40.0–56.66%) that problem was faced due to short sleeves of gown, women feel unsafe from external agents, due to long and loose fitting of the gown at chest, waist and hip gown got rolled and wrapped around the body, for other activity holding and managing gown by one healthy hand was difficult and apparel with a zipper attached to their openings were unmanageable as it was difficult to pull them up by other hand and felt discomfort.

Table 2 revealed the evaluation of Punjabi Kameez for suitability on the basis of constructional features. Cent percent arm-fractured women reported that their personal experience regarding Design I Punjabi Kameez with set-in sleeves with loose armhole was excellent; design of full front opening was comfortable; due to

Table 2 Evaluation of Punjabi Kameez for suitability on the basis of constructional features

Design I	Suitability WMS	Design II	Suitability WMS
Design of Kameez	3.0**	Design of Kameez	**2.66**
Performance of fabric	3.0**	Performance of fabric	**3.0****
Kameez sleeve set in armhole	3.0**	Kimono type sleeve	**1.66**
Length of Kameez (40 in.)	3.0**	Length of Kameez (35 in.)	**2.66**
Length of sleeve	3.0	Length of sleeve	**2.66**
Width of armhole	3.0	Width of armhole	**2.66**
Roll collar (gents)	3.0**	Narrow collar (Nehru shirt)	**1.00**
Front placket (full opening 38 in.)	3.0**	Front placket (15 in. opening)	**1.00**
Design of patch pocket		Fabric loop for tieing of handkerchief	**1.00**

Highly suitable/acceptable—3
Suitable/acceptable—2
Somewhat suitable/acceptable—1

collar, the neck was protected from the friction of cord and could avoid the development of wound at the neck; opening of sleeves from shoulder to the wrist was best and easily slides plastered hand in sleeve armhole and felt like a sleeveless garment; and closing of fastener was convenient with healthy hand and found to be highly suitable. The design of patch pocket with flap preferred more by the arm-fractured women and WMS was noted as about 3.0 and found to be highly suitable to keep mobile, medicine and handkerchief.

In the case of Design II of Punjabi Kameez with Kimono sleeves, arm-fractured women expressed their preferences for the design of Kameez. Length of Kameez, length of sleeve and width of armhole of sleeves were found to be suitable with WMS recorded as 2.66. Front bodies placket of half-size, i.e., 15 in. found to be somewhat suitable (WMS 1.66) because while wearing of Kameez it required the help of other person and further they reported that narrow width of Nehru collar was not beneficial because the cord of plaster hand slides down on the neck and causes trouble; fabric loop at the shoulder for tieing of a handkerchief for the frequent use was not acceptable. It was clear from the result that Punjabi Kameez Design I and direction of sleeve opening Design-A was found to be highly suitable, acceptable and comfortable to wear independently.

Table 3 illustrates the evaluation of different directions of placket/opening on sleeve for suitability for plastered hand. Sleeve opening at fold line outside of arm from shoulder to wrist was found to be highly suitable, and to handle the fasteners with other healthy hand with WMS recorded is 3.0. Sleeve opening from neck collar bone to wrist and sleeves opening to seam line from the underside of the arm to the wrist was reported to be not suitable because plastered hand needed to be raised, placket was spread to collect two parts of seam edges of sleeve and fastening of fasteners was found to be difficult with other hand and help of other persons was required. Therefore, Design B and Design C of sleeve placket were not suitable as per the views expressed by arm-fractured women and WMS was noted as 1.00. From the result, it is clear that the sleeve opening of Design A was found to be highly suitable, acceptable and comfortable to handle by the arm-fractured women.

It was observed from Table 4 that press buttons were found to be highly suitable

Table 3 Evaluation of different directions of openings for suitability given on sleeve for plastered hand

Direction of sleeve opening	Suitability WMS
Design A: At the fold line of the sleeve, an opening was provided from shoulder to wrist	3.0**
Design B: Sleeve opening was provided from neck collar bone level to wrist	1.00
Design C: Underside of the arm of sleeve opening was designed to seam line	1.00

Highly suitable/acceptable—3
Suitable/acceptable—2
Somewhat suitable/acceptable—1

Table 4 Suitability of different types of fasteners

Fasteners	Suitability WMS
Press button	3.0**
Velcro fastener	1.66
Zipper fastener	1.00
Durability of fastener during care • Press button • Velcro fastener • Zipper fastener	3.00** 1.00 1.00

Highly suitable/acceptable—3
Suitable/acceptable—2
Somewhat suitable/acceptable—1

and acceptable with higher WMS as 3.00, followed by Velcro fastener at the second rank for somewhat suitable and acceptable with WMS recorded as 1.66 because while removing Velcro tape, crackled sound was developed, and after repeated washing the sticking capacity of it was reduced. Fastener zipper coil was noted as not suitable because it was difficult for women to close with one hand and WMS was noted as 1.00. It was clear from the table that press buttons of big size were highly suitable for placket of sleeves as well as for the front opening of Punjabi Kameez. Press button was found to be durable in multiple washing with WMS as 3.00.

4 Conclusion

From the study, it can be concluded that the arm-fractured women suffered from different problems in putting on and taking out of their clothes. Taking into view the problems faced, two designs of Punjabi Kameez were developed and stitched. Results showed that as per the practical experiences of wear trials of the arm-fractured women, Kameez designed with special features like full-length front opening using suitable fasteners, set-in sleeve with large armhole, gent's roll collar, full-length sleeves with side sleeve opening using press buttons as fasteners and big-sized flap pocket at waistline was reported to be highly acceptable, suitable and comfortable for the arm-fractured women.

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Chapter 15
Drudgery Reduction Through the Use of Handheld Fertilizer Applicator

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1 Introduction

The use of commercial fertilizers has increased steadily over the past decades. Fertilizers are applied to the soil to increase the available supply of plant nutrients—namely nitrogen, phosphorus and potassium to promote greater yields or better crop quality. The different methods of application of solid fertilizers are broad casting, placement, band placement and pellet application.

The fertilizers are available in dryland liquid formations. Uniform distribution and proper placement of them will continue to become increasingly important as factors in producing maximum crop response at minimum cost. Improvement of application equipment and techniques to permit the effective use of smaller dosages of chemicals and also to reduce harmful residues has become increasingly important as one means of minimizing the problems associated with the use of chemical pesticides.

Broad casting refers to spreading fertilizers uniformly all over the field and is generally used for nitrogenous fertilizers in closely sown crops like paddy and wheat. In placement methods, the fertilizer is applied to the soil at a specific place with or without reference to the seed, though different methods such as deep placement and localized placement are adopted for cereal crops, sugarcane and cotton. Band placement techniques include placement of fertilizer in bands, namely hill placement and row placement. This technique is practiced for cereals and for the application of fertilizers in orchards. Pelleting techniques are generally used for paddy crops where nitrogenous fertilizers are applied in the form of pellets.

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Of all the above methods of fertilizer application, placement of fertilizers has the following advantages.

- The weeds all over the field cannot make use of the fertilizers
- Residual response of fertilizers is usually higher
- Utilization of fertilizers by plants is higher
- Loss of nitrogen by leaching is reduced
- Being, immobile, phosphates are better utilized where placed.

Women participate in various agricultural operations such as seeding, transplanting, weeding, fertilizer applications, plant protection, harvesting, processing, selling and looking after animals. Drudgery is generally conceived as physical and mental strain, agony, monotony and hardship experienced by human beings while all women in this regard suffer the most due to the heavy burden of drudgery on them (Sharma et al. 2018). Though women participate mainly in sowing and weeding operations, a section of the women is also involved in fertilizer application. A handheld fertilizer applicator has been designed based on the anthropometric measurements of farm women and an attempt has been made to study its impact in terms of drudgery reduction of farm women.

2 Methodology

2.1 Design of Study

The design followed for the study is a randomized block design (Table 1). The experiments have been carried out in the AC&RI campus, Madurai and also in the farmer's field at Madurai.

(i) **Selection of subjects**

Six healthy female subjects who were willing to participate in the study were selected from among the farmworkers employed in the agricultural activities. All the subjects had more than 10 years of experience in performing agricultural activities.

Table 1 Design of the study

S. no	Treatment	Levels
1	Application of solid fertilizers	B1—Handheld fertilizer applicator
		B2—Conventional
2	Subjects	6 (S1–S6)
3	Replications	3
4	No. of experiments	2 × 6 × 3

Fig. 1 Conventional method of fertilizer application

(ii) **Method of application of fertilizer**

Two methods of application of solid fertilizer were studied. Each of the subjects was trained to use the handheld fertilizer applicator and all the subjects were familiar with the conventional method of fertilizer application. During the conventional method of fertilizer application, the worker has to bend to place the fertilizer near the root zone and also need to be careful to avoid wastage of fertilizer (Fig. 1).

The handheld fertilizer applicator is a less weight, simple and user-friendly tool made of PVC pipe. The total height of the tool is 140 cm. The bottom portion of the applicator has an inverted 'T' shaped pipe to facilitate pressing the applicator against the ground. During this action of pressing, the required quantity of fertilizer is dropped near the plant during a single press (Fig. 2).

(iii) **Measurement of heart rate**

A portable HR monitor was used to measure the heart rate during the fertilizer application process. Before starting an experiment all functions of the monitor were set as per the instructions given in the manual. Sufficient rest was given to the subject before starting an experiment to make the heart rate stable. The experiment was carried out after recording the resting heart rate (RHR) and also working heart rate (WHR). On completion of the fertilizer application process, the recovery heart rate was recorded. From the downloaded data, the value of HR was taken for the calculation of working HR as the physiological responses of the subjects.

(iv) **Energy expenditure**

The energy expenditure of the subjects was derived using the Varghese et al. (1994) equation from the heart rate method (Mehta et al. 1934).

Fig. 2 Fertilizer application using handheld fertilizer applicator

3 Results and Discussions

Studies have shown that feminization of agriculture is already happening; its causes and consequences have increased on the drudgery for women.

Table 2 presents the physiological characteristics of the selected subjects for carrying out the field trials.

The average age of the subject was 46 years and had a normal BMI. They did not have any major health ailments.

Table 3 presents the time taken to apply fertilizer for a 10 m ridge using the conventional method and improved method (using fertilizer applicator). The time taken for each ridge is given in Table 3 and the mean time taken to complete one ridge ranged from 11 to 14 s while using a handheld fertilizer applicator. The conventional method of applying fertilizer ranged from 16 to 18 s to complete one ridge. Further video analysis revealed that the workers tend to take microbreaks between the works

Table 2 Physiological characteristics of the subjects

Subjects	Age (in years)	Body weight (kg)	Height (cm)	BMI (kg/m^2)
S_1	48	50	158	20.03
S_2	47	42	152	18.18
S_3	53	60	157	24.34
S_4	41	54	156	22.19
S_5	45	52	150	23.11
S_6	42	51	155	21.15
Mean	46	51.5	154.7	21.49

Table 3 Time taken to apply fertilizer using the conventional and improved method

Subjects	Time[a] (Sec)														
	R1		R2		R3		R4		R5		R6		Mean		Paired t-test
	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2	
S1	21	14	20	15	19	16	20	13	18	12	18	14	18.33	14.17	4.579**
S2	18	12	17	13	16	12	14	12	17	11	15	10	18.33	14.33	10.954**
S3	18	17	22	18	20	17	14	11	19	10	20	16	18.67	13.50	4.794**
S4	20	15	17	14	18	12	17	13	20	14	19	12	16.33	13.00	3.952**
S5	17	14	19	14	21	11	16	15	17	12	21	11	17.83	11.67	10.262**
S6	16	13	15	12	18	13	17	14	16	11	19	14	18.67	12.83	6.167**

[a]Time taken to complete 10 m ridge
S(1–6)—Subjects, R(1–6)—ridges
B1—Conventional method, B2—Handheld fertilizer applicator
**$P < 0.01$

which was not observed while using the improved method of fertilizer application. Thus there is saving in time by around 26%.

A good working posture is considered as one which requires minimum static muscular effort to maintain that posture. For long-duration jobs, a standing posture is preferred instead of bending or squatting posture. Also, a sitting posture is always better than a standing posture, if the work can be done in that posture (Varghese et al. 1994).

Table 4 presents the physiological responses during different methods of fertilizer application. The average heart rate during the conventional method of fertilizer applicator ranged from 112 to 125 bts/min as against 101 to 109 bts/min while using fertilizer applicator. The mean heart rate during fertilizer application was 118 bts/min during the conventional method (by bending and applying fertilizer to the low-level plants). However, the average heart rate during the improved method was 109 bts/min indicating a reduction in physiological stress by 8%.

Table 4 Physiological parameters assessed for fertilizer applicator and conventional method

Subjects	Conventional method		Fertilizer applicator		Paired t-test	
	HR	Energy expenditure (kJ min^{-1})	HR	Energy expenditure (kJ min^{-1})	HR	Energy expenditure (kJ min^{-1})
S_1	112	11.5	101	9.7	5.501**	11.527**
S_2	115	12.6	109	10.2		
S_3	119	10.6	102	8.7		
S_4	121	9.7	115	7.6		
S_5	120	12.4	110	9.8		
S_6	125	11.9	118	10.5		

The energy expenditure was around 11 kJ/min during the conventional method which was reduced to 9.4 kJ/min while using the improved method. Thus there was a reduction in the energy expenditure by 17%. Here, the use of fertilizer applicator enabled a reduction in heart rate and energy expenditure. Research and project assessment studies in India indicate that women's participation and their drudgery can be effectively minimized by the use of gender-friendly technologies (Parimalam and Padmanathan 2020). Saving in cardiac cost of a worker per ha with a refined broadcaster in comparison to traditional practice was found to be about 6% (Signh and Signh 2009). The average working heart rate for firewood collection as reported by Borah, 2015 for women in the age group 36–50 was 132 bpm (Borah 2015). A comparative study of weeding operation by using three different weeders indicated heart rate ranging from 97 to 116 bpm, with energy expenditure in the range of 10–13 kJ/min (Premkumari et al. 2018). Similarly, the average heart rate during de-husking of maize cobs in a sitting posture was 103 bpm (Signh 2015). Harvesting using different sickles like Naveen, Vaibhav and local sickle had a heart rate of 103, 107 and 106 bpm, respectively (Signh 2012). All these studies indicate that the working heart rate for different agricultural operations ranged from 100 to 140 bpm.

Similarly, Drudgery Index indicated that weeding was the highest with Drudgery Index of 60.66 following trash mulching (59.66) and harvesting (54.66) (Ojha et al. 2017). Thus, the studies in agriculture in the Indian context indicate a majority of the operations in agriculture are drudgery prone when performed manually. Thus, there is a need to innovate tools that can reduce drudgery among women.

4 Conclusion

The designed fertilizer applicator is a small hand tool that can discharge fertilizers in varying quantities such as 1, 2, 2.5 g depending upon the need. The use of this fertilizer applicator device could help in saving fertilizer. There was a reduction in energy expenditure by 17% when compared with the conventional method and savings in time by 26%.

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Chapter 16
Dynamic Analysis of Load Carriage on Physiology and Biomechanics During Simulated Terrain Walking: A Continuous Observational Approach

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1 Introduction

Despite the rapid advancement of technological development, load carriage is an important and major necessary task for both indoor and outdoor daily activities especially in physically demanding occupations like dismounted military operations and recreational activities including mountain hiking (Datta and Ramanathan 1971; Knapik et al. 2004, 2012; Stuempfle et al. 2004; Beekley et al. 2007; Bohne and Abendroth-Smith 2007; Liu 2007; Simpson et al. 2011; Majumdar et al. 2013; Pal et al. 2014; Mullins et al. 2015; Orr et al. 2015; Paul et al. 2015; Chatterjee et al. 2017; Maupin et al. 2019). During military operations, infantry soldiers must carry equipment and move, on foot, over various rough and slopped terrains for long and continuous periods (Simpson et al. 2011; Patton et al. 1991; Blacker et al. 2010). Since the middle of World War II, military load carriage researches were being carried out to optimize the ease of such carriage, but load carriage again is highly related to the varying grade, walking speed, surrounding environment, design of carriage unit and users' comfort (Knapik, et al. 1990).

The physiology of load carriage, particularly the effect of load positioning, has been extensively investigated (Pelot et al. 1995; Quesada et al. 2000; Birrell and Haslam 2010; Drain et al. 2010; Zhang et al. 2010; Billing et al. 2015; Taylor et al. 2016; Godhe et al. 2020; Liu et al. 2020; Sessoms et al. 2020). Previous studies have identified that load carriage significantly altered work capacity, metabolic demand,

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physiological strain and subsequently increased the risk of injury (Taylor et al. 2016). Relative to level walking, the uphill movement with load requires more energy due to vertical displacement of total body mass while downhill load carriage involves a decrease in some physiological parameters but an increase in relative workload (Blacker et al. 2010). On the other hand, a few investigators have examined the effect of load carriage on gait biomechanics and reported that a load of less than 21% of the bodyweight altered the spatiotemporal gait parameters like cadence, gait velocity, double support time, stride length and stride rate, which could be a compensatory mechanism to minimize the gait instability or musculoskeletal strain (Singh and Koh 2009). They have also found a negative relationship between carried load and stride length (Harman et al. 2000). Along with that, another particularly important biomechanical change in response to carrying load is trunk forward tilt, to counterbalance the load (Attwells et al. 2006). Such forward inclination of the trunk occurred to counter posterior shift of the combined center of mass (CoM) of the body and load carried. On the other hand, during both upslope and downslope walking kinetic parameter 'support moment' increased significantly (Lay et al. 2006). The increase was significantly related to the increased hip extensor moment and increased knee extensor moment during uphill and downhill walking, respectively. There are, however, very few studies that have attempted to investigate the biomechanical changes during the carriage of load at slopes (Lee et al. 2017). Surprisingly to date, no study was carried out to evaluate the underlying correlation between the biomechanical and physiological variables during carriage of load at different slopes.

Here the present study was designed to evaluate the effect of moderately heavy load carriage on physiological and biomechanical responses during continuous positive and negative slope walking. The major focus of the experimental design of the current study was to simulate the military load carriage on hilly terrain. Further, we aimed to correlate the biomechanical and physiological responses for optimization of load selection and prediction of combat readiness.

2 Methods

2.1 Subjects

Twelve healthy male Indian infantry soldiers were recruited for this study where they were free from any type of musculoskeletal injury. After being informed of the purpose and possible risks of this study, a written informed consent was obtained from each subject. An institutional approval from the ethical review committee was also obtained for all procedures which conforms with the recommendations of the Declaration of Helsinki (Association 2013). The mean ± SEM age, height and body mass were (27.1 ± 1.04) yrs, (1.7 ± 1.15) m and (66.2 ± 1.85) kg, respectively.

Mode	Weight	Components	% of body weight (BW)
No Load	0 kg	Vest, shorts which have little load	0%
Existing load carriage ensemble of Indian Army	10.7 kg	Haver sack (HS)- in the waist, Webb (Wb)- in front waist region, Rifle-in hand	16.2%
Do	21.4 kg	Backpack (BP)- back, HS, Wb, Rifle as mentioned above	29.3%

Fig. 1 Description of load carriage ensembles with load magnitudes and respective percentage of bodyweight

Participants wore their own similar type of military shoe and minimal hosiery across all gradients of gait conditions.

2.2 Testing Procedures

Before the inception of the actual experimentation, subjects were accustomed to laboratory procedures by allowing them to walk on a motorized treadmill with different loads and gradients. Thereafter, each subject performed 30 trials at a specified speed of 3 km/h (0.833 m/s) with three load conditions (0, 10.7 and 21.4 kg) and ten gradients (0, 5, 10, 15, 20, −20, −15, −10, −5 and 0%). All these two loads (Fig. 1) were typical operational load carriage conditions of Indian infantry soldiers. A maximum of two trials of continuous uphill and downhill load carriage was performed by the same subject each week and at least 3 days separated successive trials. The trials order was randomly assigned, and subjects reported at the same time each day to minimize training and time effects, respectively.

2.3 Physiological Measurement

A breath-by-breath metabolic measurement instrument (K4b2, COSMED, Italy) was used to collect the physiological variables (oxygen consumption (VO2), heart rate (HR), minute ventilation (VE), energy expenditure (EE) and relative workload (%VO2)) during all gradient load carriage operations. Prior to each test session, a gas analyzer of the portable system (K4b2, made up of open circuit technology) was calibrated for room air, volume and known standardized oxygen and carbon dioxide gas mixture concentration. All physiological variables were recorded continuously (60 min for each subject, i.e., 6 min × 10 gradients) during walking with all loaded conditions. Mean values of the last 1 min (6th min) of each 6 min gradient load carriage walking, for each participant, were considered for further analysis.

2.4 Biomechanical Measurements

A high-speed, six-camera-based optical motion analysis system (Motion Analysis Crop, Santa Rosa, CA, USA) captured treadmill load carriage operation at 100 Hz. Data were obtained from the last minute of each 6 min condition to ensure that each participant's gait had been stabilized. 3D gait data were collected for the kinematic analysis of the lower body during a different combination of load carriage operations. Twenty-five passive retroreflective markers (Helen Hayes) were used to collect the 3D data. The participants were asked to stand at the middle of the treadmill for static data collection, so the stick diagram structure would generate the kinematic data for all load carriage operations. After collecting the 3D data, it was processed through a software (Cortex) for observing smooth video simulation of load carriage and then this video data was processed through another software platform (OrthoTrack) to get the clinical gait analysis data. Spatiotemporal and sagittal plane trunk, hip, knee and ankle angular variables (i.e., peak angles) and their range of motion (ROM) were analyzed to interpret the effect of different modes of load carriage operation in the existing backpack.

2.5 Statistics

Statistical analysis was conducted using SPSS (version 21.0, IBM, USA). The significance level was set at $p < 0.05$. Mean (SEM) of physiological and biomechanical variables with respect to different loads and inclinations was analyzed for descriptive statistics. To assess for differences between conditions, a two-way (load × gradient) repeated measure ANOVA was conducted to establish any significant main effects and interactions, accounting for variability across the whole study. In case of significance, a Bonferroni post-hoc test was performed for pairwise comparison. Effect sizes for repeated measures of ANOVA were calculated using partial eta squared ($\eta p2$). Further, the Pearson correlation test was performed to study the association between physiological variables and gait parameters.

3 Result

Different load magnitude and grades significantly affected both physiological and biomechanical variables, during continuous uphill and downhill load carriage operations, as follows.

Heart rate (HR), a major and prime indicator of physiological variable, exhibited significant load effect [$F (2, 22) = 42.16$, $p < 0.0001$, $\eta p2 = 0.79$], gradient effect [$F (2.42, 26.71) = 276.42$, $p < 0.0001$, $\eta p2 = 0.96$] and load × gradient interaction [$F (18, 198) = 28.14$, $p < 0.0001$, $\eta p2 = 0.71$]. Pairwise comparison reveled significant differences of HR between load 0 kg and 10.7 kg ($p = 0.02$), 0 kg and 21.4 kg ($p = 0.0001$) and 10.7 kg and 21.4 kg ($p = 0.0001$). Further, it was also observed that HR were highest during peak uphill carriage at 20% but when the slope become downhill a 33.5% reduction took place even when slope remained 20%.

Oxygen consumption (VO2), which holds great relevance in understanding human metabolism, showed significant load, gradient effect and interaction of both of these two factors at [$F (2, 22) = 136.68$, $p < 0.0001$, $\eta p2 = 0.92$], [$F(2.64, 29.13) = 1320.15$, $p < 0.0001$, $\eta p2 = 0.99$] and [$F (18, 198) = 20.77$, $p < 0.0001$, $\eta p2 = 0.65$] level, respectively. Like HR, VO2 exhibited maximum response during carriage of 21.4 kg load. In addition, at uphill conditions, with the gradient increase the VO2 increased about 58% from 0 to 20%, but at downhill carriage with the decrease of gradient the responses decreased surprisingly about 19% from 20 to 0%.

Minute ventilation (VE) which is considered as a key factor for maintaining physiological homeostasis had significant load, grade and load × grade interaction effect at [$F (2,22) = 97.04$, $p < 0.0001$, $\eta p2 = 0.89$], [$F (1.63, 17.94) = 277.34$, $p < 0.0001$, $\eta p2 = 0.96$] and [$F (18, 198) = 31.13$, $p < 0.0001$, $\eta p2 = 0.73$] level, respectively. Further, on pairwise comparison for load magnitude, 21.4 kg load significantly showed more response than no load ($p = 0.0001$) and 10.7 kg load ($p = 0.0001$). Thereafter with increasing gradient VE increased linearly and with decreasing gradient it exhibited a linear decline. Surprisingly, while decreasing the response of VE with decreasing gradient it showed the decreasing trend up to −5%. At −0% the response again increased as it mimics the level walking.

Energy expenditure (EE), the amount of energy an individual uses to maintain essential body functions and as a result of physical activity, had significant load, grade and interaction effect of both of these two factors at [$F (2, 22) = 158.05$, $p < 0.0001$, $\eta p2 = 0.93$], [$F (1.96, 21.61) = 791.16$, $p < 0.0001$, $\eta p2 = 0.98$] and [$F (18, 198) = 24.22$, $p < 0.0001$, $\eta p2 = 0.68$] level, respectively. Considering load magnitude response, all load conditions were significantly altered from each other and exhibited an order of 21.4 kg > 10.7 kg > no load for EE. On the other hand, for gradient change, increasing responses of EE were observed during uphill and decreasing responses were also observed during downhill but at 0% the energy expenditure did not follow the decreasing pattern.

Relative workload (RWL) was the measure of perentage of maximum oxygen consumption of the subject's particular work. RWL had significant load effect [$F (2, 22) = 144.06$, $p < 0.0001$, $\eta p2 = 0.92$], gradient effect [$F (2.55, 28.06) = 1149.13$,

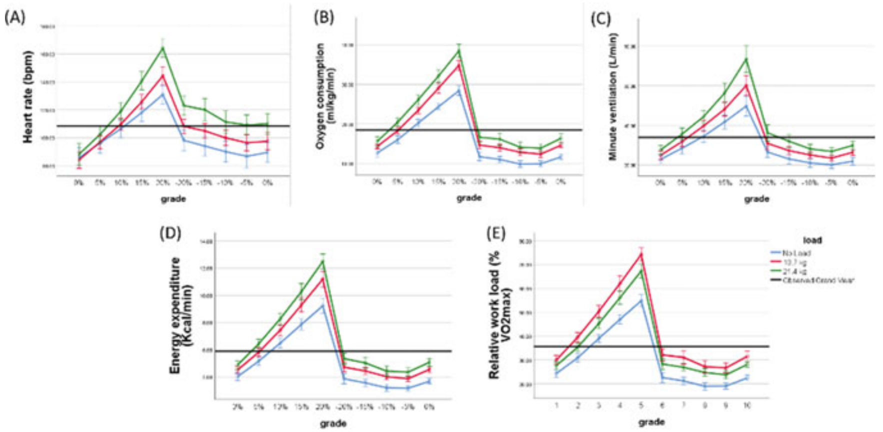

Fig. 2 Changes of physiological variables during uphill and downhill load carriage operations with grand mean value (black line)

$p < 0.0001$, ηp2 = 0.99] and interaction of load × gradient effect [F (18, 198) = 20.66, $p < 0.0001$, ηp2 = 0.65] on continuous uphill and downhill load carriage operation. Further, post-hoc test for Bonferroni correction revealed that 10.7 kg load significantly exhibited more RWL than no load and 21.4 kg load condition, while all uphill gradients showed significant difference with each of the uphill and downhill gradients, but during downhill walking RWL decreased up to a certain limit. All the physiological changes at uphill and downhill gradients of load carriage operation are shown in the line graph (Fig. 2).

Cadence has a character of controlling human performance and therefore has prime importance in gait biomechanics. It had exhibited a significant gradient effect [F (2.65, 29.20) = 49.42, $p < 0.0001$, ηp2 = 0.81] and also interaction of load × gradient [F (18, 198) = 3.23, $p < 0.0001$, ηp2 = 0.22]; instead it did not show any load effect. During uphill gradient load carriage, the cadence showed a linear decrease and walking from steep to down gradient also showed the same trend. For total support time (TST), the load magnitude and interaction between grade and load did not exhibit any significant effect but the gradient had a significant effect at [F (3.96, 43.57) = 31.38, $p < 0.0001$, ηp2 = 0.74] level. In addition, most of the uphill TST values had a significant higher responses than downhill gradients responses except 0% at downhill conditions. Single support time (SST) showed significant grade effect [F (9, 99) = 22.46, $p < 0.0001$, ηp2 = 0.67] and interaction effect of load × grade [F (18, 198) = 1.71, $p < 0.05$, ηp2 = 0.13], yet the load magnitude effect was silent. During uphill load carriage, the SST decreased as inclination increased; even it also decreased during decreasing downhill gradient. A pairwise comparison revealed that most SST values of uphill had significant differences from downhill SSTs, while some down gradient SST also significantly altered than that of other downhill SST. The initial double support time (IDST) was significantly altered by gradient [F (3.52, 38.81) = 24.66, $p < 0.0001$, ηp2 = 0.69] but not affected by load magnitude. During

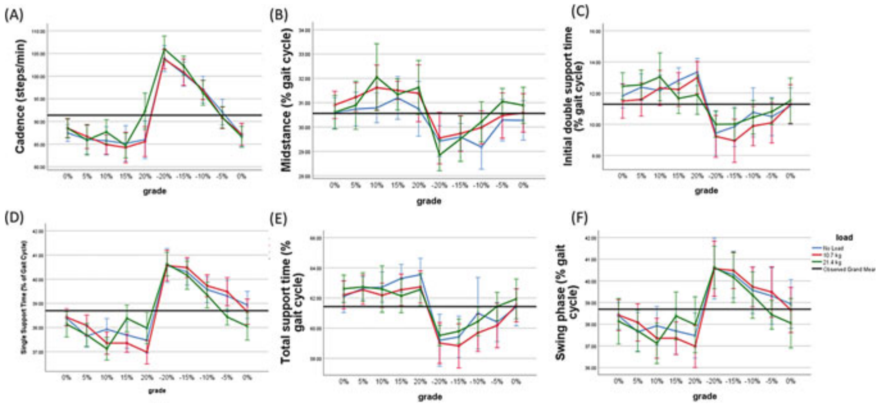

Fig. 3 Alteration of temporal and spatial variables of gait during simulated load carriage at uphill and downhill gradients. The grand mean value showed in black line

uphill walking IDST increased with increasing gradient while the same pattern was observed even in downhill gradient. Further, all uphill IDST significantly increased from downhill MST except 0% at downhill. The first half of the gait cycle which accounts for 20–30% of the gait cycle is known as midstance (MST) and was also significantly altered by gradient factor [F (9, 99) = 13.21, $p < 0.0001$, $\eta_p^2 = 0.54$] but not affected by load magnitude. Load carriage task increased the MST with increasing and decreasing gradient conditions. A few MST values at uphill gradients significantly increased from some of the downhill gradients. The swing phase also had significant gradient effect [F (9, 99) = 22.46, $p < 0.0001$, $\eta_p^2 = 0.67$] and interaction effect [F (18, 198) = 1.71, $p < 0.05$, $\eta_p^2 = 0.13$], yet no-load effect was observed. Load carriage at uphill gradients induced gradual decline of swing phase while the same was observed during downhill load carriage. All changes in temporal-spatial variables during carrying different loads at various gradients have been depicted in Fig. 3.

For angular kinematic data, peak flexion, extension and range of motion (ROM) have been analyzed to interpret the effect of load and grade on continuous uphill and downhill walking. Hip peak flexion angle was significantly altered by load [F (2, 22) = 16.15, $p < 0.05$, $\eta_p^2 = 0.59$], grade [F (2.82, 31.09) = 195.95, $p < 0.05$, $\eta_p^2 = 0.94$] and interaction of load × grade [F (18, 198) = 2.31, $p < 0.01$, $\eta_p^2 = 0.17$]. Further, with the increase of load magnitude, peak flexion decreased and Bonferroni pairwise comparison exhibited significant differences between each load with the other. For gradient consideration, peak flexion of the hip increased with an increasing gradient in the uphill and a decreasing gradient in the downhill. Pairwise comparison showed most of the gradients significantly altered from each other. Similar to hip flexion, peak extension angle also showed significant load effect [F (2, 22) = 24.73, $p < 0.05$, $\eta_p^2 = 0.69$], gradient effect [F (2.62, 28.84) = 20.57, $p < 0.05$, $\eta_p^2 = 0.65$] and interaction effect of load × gradient [F (18, 198) = 2.43, $p < 0.0001$, $\eta_p^2 = 0.18$]. Peak extension of hip exhibited more extension with the higher magnitude of load carriage while uphill carriage induced gradual decrease in extension, but downhill carriage showed opposite phenomenon. Hip ROM only had a gradient effect [$F(2.74, 30.22) = 97.06$, $p < 0.0001$, $\eta p2 = 0.89$]; instead, it showed an increasing trend with increased load magnitude. During continuous uphill and downhill gradient walking gradual increase of hip ROM was observed and most of the gradients showed significant differences from their either uphill or downhill gradients ROM. Knee peak flexion angle also showed significant gradient effect [$F(1.91, 21.03) = 21.87$, $p < 0.0001$, $\eta p2 = 0.66$] only. In pairwise comparison, most uphill peak flexion values exhibited significant lower differences than downhill flexion values, whereas few downhill peak flexions also showed significant differences among them. On the other hand, knee peak extension showed gradient effect [$F(9, 99) = 5.02$, $p < 0.0001$, $\eta p2 = 0.31$] and interaction effect of load × grade [$F(18, 198) = 1.77$, $p < 0.05$, $\eta p2 = 0.13$]. Peak extension gradually increased with the increase of gradient while reduced with a gradual decrease of the gradient. Knee ROM only exhibited gradient effect [$F(2.68, 29.47) = 12.87$, $p < 0.0001$, $\eta p2 = 0.53$], and the gradual decrease was observed in both uphill and downhill load carriage operations. The grand mean for knee ROM was 68.73°. The ankle peak dorsiflexion angle did not show any significant effect of load, gradient and interaction of these two factors. In addition, with higher load carriage peak dorsiflexion increased and during uphill carriage it gradually increased too. During downhill carriage, the dorsiflexion angle decreased gradually but the effects were not significant. The ankle peak plantarflexion angle only had a significant gradient effect [$F(316, 34.80) = 4.47$, $p < 0.0001$, $\eta p2 = 0.28$], and a gradual increase of plantar flexion was observed during uphill walking, and there was a gradual decrease presented during downhill walking. For ankle ROM, again no significant effect of load, grade and their interaction were observed. With the increase of load magnitude, the ankle ROM showed an increasing pattern while both gradual increase and decrease patterns were observed during uphill and downhill load carriage operations, respectively. The trunk peak forward tilt exhibited significant load effect [$F(2, 22) = 20.94$, $p < 0.0001$, $\eta p2 = 0.65$], gradient effect [$F(9, 99) = 172.22$, $p < 0.0001$, $\eta p2 = 0.94$] and interaction effect [$F(18, 198) = 2.97$, $p < 0.0001$, $\eta p2 = 0.21$]. For pairwise comparison, all loads significantly altered among themselves while the forward tilt angle in most of the gradients significantly changed with their downhill and uphill gradients. The peak forward tilt increased with both increasing and decreasing gradients. Likewise forward tilt, trunk peak backward tilt also showed significant load effect [$F(2, 22) = 7.82$, $p < 0.01$, $\eta p2 = 0.41$], gradient effect [$F(9, 99) = 7.94$, $p < 0.0001$, $\eta p2 = 0.41$] and interaction effect [$F(18, 198) = 3.40$, $p < 0.0001$, $\eta p2 = 0.23$]. During higher load carriage peak backward tilt tend to be reduced and tilt toward forward. Further, the uphill gradient induced a gradual reduction of backward tilt while the changes in the downhill gradient almost remain the same. Lastly, the trunk ROM exhibited gradient effect [$F(9, 99) = 15.40$, $p < 0.0001$, $\eta p2 = 0.58$] and interaction effect [$F(18, 198) = 1.90$, $p < 0.05$, $\eta p2 = 0.14$] but the load effect was suppressed. With the increase of uphill gradient, trunk ROM increased gradually and during the decrease of downhill gradient it increased too. Most ROMs of uphill gradient (Fig. 4) had significant differences from downhill

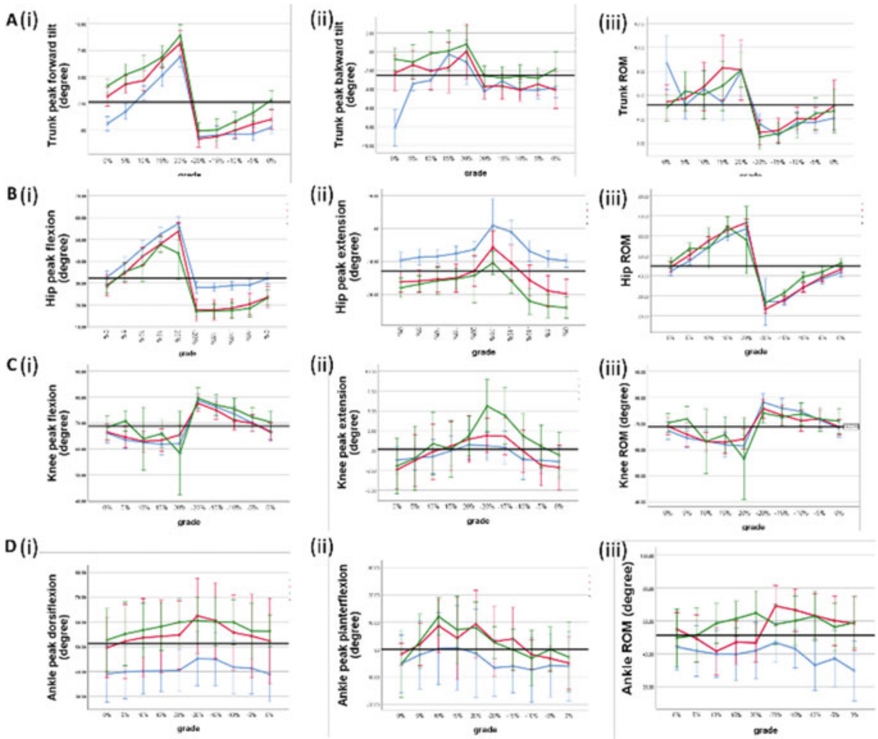

Fig. 4 All angular changes have been presented with their three-dimensional way at midstance of the gait cycle. The grand mean value has been showed with each of the variable (black line)

gradient ROMs (Fig. 4). A diagram of all angular changes with grade and load magnitudes is shown in Fig. 4.

A Pearson correlation analysis was conducted between physiological variables and biomechanical variables. The outcome revealed that most of the physiological variables had either significant positive or negative correlation with biomechanical variables which has been computed in Fig. 5. The spatiotemporal parameters like cadence and SST had a significant lower negative correlation with most of the physiological variables while other temporal variables like TST, IDST, MST and swing phase had a significant lower positive correlation (Fig. 5). On the other hand, angular variables of trunk, hip and knee showed a similar positive and negative correlation between both physiological and biomechanical variables. Trunk peak anterior tilt, peak posterior tilt, hip peak flexion and ROM angles exhibited a significant lower positive correlation with selected physiological variables, while trunk ROM, knee peak flexion and ROM angular variables showed a lower negative correlation with selected physiological variables (Fig. 5).

	CADNCE	TST	IDST	MST	TS	SST	SP
HR	-.068	.172**	.190**	-.178**	.081	-.178**	-.172**
VO2	-.344**	.367**	.354**	-.393**	.255**	-.393**	-.367**
VE	-.246**	.281**	.303**	-.333**	.169**	-.333**	-.281**
EE	-.365**	.377**	.374**	-.404**	.247**	-.404**	-.377**
RWL	-.393**	.359**	.344**	-.403**	.262**	-.403**	-.359**

Pearson correlations analysis among physiological variables and spatio-temporal variables of biomechanics. (*p < .05, **p < .01)

	HIP ANGL	KNEE ANGL	ANKLE ANGL	TRUNK ANGL	PELVIC ANGL	HIP ROM	KNEE ROM	ANKLE ROM	TRUNK ROM	PELVIC ROM
HR	.420**	.594**	-.133*	.330**	-.007	.448**	-.234**	.011	.233**	-.016
VO2	.713**	.869**	-.176**	.433**	-.099	.762**	-.419**	-.138**	.435**	-.097
VE	.627**	.746**	-.209**	.352**	-.107*	.660**	-.255**	-.083	.350**	-.059
EE	.719**	.824**	-.225**	.391**	-.109*	.762**	-.351**	-.125*	.407**	-.086
RWL	.742**	.821**	-.209**	.387**	-.064	.757**	-.365**	-.106*	.433**	-.065

Pearson correlations analysis among physiological variables and kinematic variables at mid stance of gait. (*p < .05, **p < .01)

Fig. 5 Correlations between physiological and temporal and spatial variables showed in the top table and bottom one showed same between physiological and angular variables

4 Discussion

Evaluating major physiological, biomechanical responses and their correlation during carriage of moderately heavy load, at slopped terrain was the major focus of experimental design in the present study. To achieve the goal, we have measured physiological parameters, e.g., HR, VO2, VE, EE and RWL, biomechanical variables like temporal (cadence), spatial (TST, SST, IDST, MST and swing phase) and angular (hip, knee, trunk and ankle peak flexion and extension and their ROM) and further evaluated correlations among the physiological and biomechanical parameters during continuous walking at four different uphill (5, 10, 15 and 20%) and downhill (−20, −15, −10 and −5%) gradients with 10.7 and 21.4 kg loads. Such an experimental setup was planned to simulate unpredicted mountainous terrain walking with patrolling loads of infantry soldiers.

As the physiological cost of uphill downhill load carriage has been of specific interest for the maintenance of optimum military performance, we have studied alterations of physiological variables in the present study. All physiological variables increased during uphill walking due to load and grade factors. For HR, during uphill load carriage, the variable increased with an increase in both grade and load, while during downhill carriage, the HR decreased with the grade but increased with the load. The remaining parameters, i.e., VO2, VE, EE and RWL (%VO2max) followed the same pattern up to 5% downhill gradient. Although a slight increase of the variables was observed at the level of walking, further, the increased physiological variables abruptly decreased while the direction of walking changed towards downhill (−20%). The metabolic demand gradually increased at uphill walking even in no-load condition that supported the findings of Margaria (1938), Williams and Cavanagh (1983) and Minetti et al. (1993). The study of Maxwell Donelan et al. (1480) suggested that humans prefer a step width involving minimal metabolic cost. Therefore, in our study, it is possible that subjects preferred higher cadence during load carriage operations to minimize the metabolic cost. A few previous physiological studies have also exhibited that UH walking required less mechanical energy exchange with a corresponding high metabolic rate (Yano et al. 2000; Navalta et al. 2004). This evidence explains the excessive energy cost of the UH load march and a comparative less energy cost of DH carriage of the present study. The abrupt decline of the metabolic cost from uphill to downhill may possibly be due to decreased impact of the counterbalance mechanism between acted external load situated on the back and forward lean caused by the load.

The biomechanical control of load carriage during uphill and downhill walking is a mechanistic part of the physiological explanation. In the present study, under spatial parameters, cadence showed significant alteration with grade. A decreasing trend of the parameter was observed during uphill as well as downhill load carriage. This may be due to the difficulty in balancing the load while working at such altered slopes. By reaching the highest level the subjects may have adjusted to the conditions, but when they tend to start downhill walking with load, they have a counterbalance mechanism from fear of falling and thus increased the step length and decreasing the cadence. This encourages us to believe that the load magnitudes used in this phase of the study were safe and had no injury potential in terms of spatial responses. Leroux et al. (2002) explained that during uphill walking, the human tendency is to maintain the body's centre of gravity within the base of support even during forward leaning of the body.

All the temporal variables studied were significantly altered with alteration of gradient at both positive and negative directions. Parameters including TST, IDST and TS showed a significant increase with alteration of gradient, irrespective of the direction of grade. But parameters like MST, SST and SP exhibited a significant decrease with alteration of gradient, irrespective of the direction of grade. The changes found in temporal parameters are due to the adjustments done in the body during carrying the load at altered gradients.

Angular variables like trunk, hip, knee, and ankle were affected dominantly by gradient, whereas a few load effects were also found. During such continuous load carriage, concentric contraction in the lower limb always facilitated the upper torso to generate forward propulsion of the body. Therefore, our results supported the previous findings of Thorstensson et al. (1984) and Vogt et al. (1999). Higher magnitude of load carriage at uphill gradient led to a significant increase and decrease in trunk forward and backward tilt, respectively, which might indicate the maintenance of body balance and corroborates the findings of Kinoshita et al. (1985), Harman et al. (2000) and Polcyn et al. (2002). During downhill gradient load carriage, the same effect was found on the trunk forward and backward tilt, and therefore, the ROM showed a significant increase, irrespective of the gradients. It could be possible that during downhill carriage the forward tilt was comparatively less than uphill load carriage conditions, but the backward tilt was more, and as a result, such significant changes occurred in the ROM of the trunk. Bobet and Norman (1984) had pointed out that trunk muscles activity was predominant than erector spinae and the carrying stress was transferred toward lower body muscles. Therefore, hip, knee biomechanical variables were significantly altered to compensate for such continuous up-down load carriage. As load carriage induced instability during continuous up and downhill walking, the subject's body always adapted some strategies to increase stability; therefore, more work was required from the hip and knee joint. These resulted in significant alterations in the hip, knee joint flexion–extension and ROM variables. On the other hand, ankle plantar flexors are considered as the key determining factors of the strategies of human locomotion (Keren et al. 1981). Interestingly, our study also highlighted the effect of two different loads and various up and downhill gradients only on the peak ankle planter flexion angle. However, integrated knowledge of both kinematics and kinetics are highly required for better understanding of biomechanical responses to load and gradients. Here in the present study, we were able to evaluate only kinematic parameters which could be considered as a limitation of our study. Further correlation analysis revealed that physiological variables were positively related with spatio-temporal variables like, TST, IDST and MST, and negatively related with cadence, SST and SP. The angular variables of hip and trunk showed positive correlation, and knee showed negative correlation with physiological variables, irrespective of the slope of walking. In addition, hip ROM exhibited positive and trunk and knee ROM showed negative correlation with physiological variables. The knowledge obtained from the correlation analysis of the present study would be very much helpful in optimizing load and safest gradient carriage.

5 Conclusion

In summary, this novel study investigated the effect of two different moderately heavy backpack load carriage during continuous uphill and downhill walking at a speed of 3 km/h. All physiological variables were gradually increased with uphill load carriage and decreased with declining gradients. Further, higher physiological and biomechanical responses were observed with moderate to higher magnitude of load carriage irrespective of the gradient. The result of the current study indicated comparatively lower responses of spatiotemporal gait parameters, but the angular changes were in accordance with the physiological findings. Overall, the study strongly indicated that carrying moderately heavy loads in real-time situations would require conscious knowledge of balance maintenance, personalized load optimization according to the physiological and biomechanical response of the body, and optimization of the training schedule.

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Chapter 17
Effect of Lifting Height and Weight Magnitude on Biomechanical Loading During Manual Lifting

Anurag Vijaywargiya, Mahesh Bhiwapurkar, and A. Thirugnanam

1 Introduction

It is now well established that o*verexertion injuries* in MMH activities are the most common type of workplace injury. It is now well established that o*verexertion injuries* during MMH activities are the most common type of workplace injury, pose *an* occupational fatigue, particularly stressful. The construction industry is labor-intensive and despite recent advancements in construction technologies, a large portion of construction workers relies largely on manual handling tasks, due to low level of automation and mechanization (Khoshnevis 2004; Ardiny et al. 2015). Also, construction workers are frequently exposed to forceful and repetitive exertions with awkward postures, which leads to work-related musculoskeletal disorders (WMSDs) such as strains, tendonitis, back and wrist injuries (Everett 1999; Boschman et al. Oct. 2012). Moreover, back pain is the most prevalent and costly musculoskeletal disorder as a result of poor working conditions (Dai et al. 2010).

Complex lifting, also known as asymmetrical lifting, occurs when the lifter is required to side bend or twist the spine during a lift. Asymmetrical lifting is a common lifting strategy for workers with a restricted vertical workspace (Gallagher et al. 2011). In the construction industry, asymmetrical lifts occur when workers have

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limited space to lift loads that aggravate back pain and increase the chances of injury (Murphy and Volinn 1999).

In order to improve MMH techniques and so as to reduce the risk of injury, researchers have analyzed the biomechanical effects of numerous performance variables along with their interaction in both lifting and carrying activities. Past studies have proven that asymmetrical spinal movements paired with spinal loading lead to an increase in back disability risk. Kucera et al. (2009) found that repetitive asymmetrical lifting movements led to an increase in back pain risk. They found unassisted lifts of large loads led to severe back pain among commercial fishermen as a result of a high volume of compressive forces on the lumbar spine. Shirazi-Adl (2006) and Fathallah et al. (1998) found that asymmetrical occupational lifts create greater forces on the spine when compared to symmetrical lifts.

Electromyographic analyses of various trunk muscles during asymmetric lifting have shown greater muscle activity on the side across from the load (Andersson et al. 1980; Kromodihardjo and Mital 1987). Further, Andersson et al. (1980) and Kromodihardjo and Mital (1987) identified the increased lateral bending moment acting on the spine due to the asymmetric load. Generally, all these researchers have stated that asymmetric lifting is more stressful than sagittally symmetric lifting.

Thus there is a need for a scientific study to investigate the effect of these manual lifting in awkward posture on the musculoskeletal system and discomfort level of the workers. Kromodihardjo and Mital (1987) developed a three-dimensional kinetic model for the analysis of dynamic lifting and analyzed GRFs for asymmetrical and symmetrical lifting and concluded that the spinal stresses are higher in asymmetrical lifting as compared to symmetrical lifting. McMullian et al. (1995) measured GRF and muscle activation asymmetries for three workers while lifting boxes from table to shoulder height. Tsuang et al. (1995) estimated the GRFs when subjects assumed upright and bending postures as well as when they lifted at low and high frequencies of lift. Amadio et al. (1999) used the GRF as an indicator of the overload level in the musculoskeletal system during the weight-bearing phase on the ground. Faber et al. (2013) proposed and evaluated the performance of a novel hand force estimation method based on GRFs and body segment accelerations during manual lifting and carrying tasks in patient handling.

Many researchers studied the vertical GRFs and loading rate on the human body during running, walking, and jumping, but few researchers have been used to evaluate the lifting task. Measurement of GRFs in different planes is a good measure of musculoskeletal stresses being exerted on the workers, performing manual lifting tasks. Therefore, there is a need to evaluate the effects of lifting parameters on the GRF and loading rate of workers in dynamic lifting human activities. The lifting task was considered similar to the task used in the construction industry in India. The objective of the study is to investigate the effect of lifting task parameters; lifting magnitude and lifting height based on subjective and biomechanical loading estimates, while lifting the object asymmetrically. The results can possibly help further progress knowledge to create new lifting guidelines. These lifting guideline improvements will lead to a decreased occurrence of injury from occupational lifting.

2 Subject and Methods

In the present study, 12 male subjects, selected purposively from the institute, aged between 20 and 25 years (weight 69.4 ± 3.55; height 171.67 ± 5.72) participated. Each of them had no prior medical history and was in good health. The study was approved by the institute's local ethics committee. Informed written consent was obtained from each subject before conducting the trial. All the subjects were trained for the task before the start of actual experimentation. The remunerations were given to the subjects for their participation in the study. The subject's mean height and weight were taken and were found to be approximately the same due to the close age group.

Subjects performed a lifting task with five different loads, in which 10 kg, 12.5 kg, 15 kg, 17.5 kg, and 20 kg round containers were used for the lifting activity. The lift was always initiated from a sagittal symmetric posture and the destination of the lift was located in the asymmetric plane (90° to the right, Fig. 1). The subject was constrained to move their feet to make the lift. The subjects were instructed to lift the load from his below knee height (origin) to five vertical destination heights: below knee, knee, waist, shoulder and ear level of the subjects. This manual lifting task was found to be consistent with the building construction industry for performing a concreting operation.

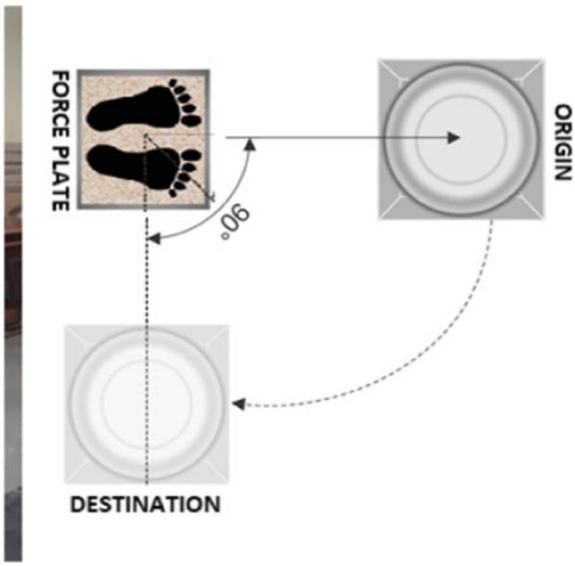


Fig. 1 Laboratory setup of force plate

3 Experimental Setup

The experimental study was performed in Biomechanics Lab of National Institute of Technology Rourkela (NIT) Rourkela (Jena et al. 2017). The force platform used in this study was Kistler's multiaxial force platform (model AA9260). The dimensions of the plate are 500×590×50 mm. This force platform can measure ground reaction forces (GRF) and moments of the body. The analog output from the force platform passes through an internal amplifier and reaches Kistler's data acquisition system (type 5691A1), where data was collected with a sampling frequency of 1000 Hz to generate a digital signal. The sampling frequency is chosen based on the sampling theorem—Nyquist theorem. The raw data collected was passed through the Butterworth filter for smoothening biomechanical data which attenuates the frequencies above the specified cut-off frequency and allows the frequencies below the cut-off to pass through the filter. Finally, the data is reflected in Bioware software.

4 Biomechanical Evaluation

The manual lifting tasks were evaluated using the force plate and subjective workload assessment by body discomfort chart (Sauter et al. 1991). The magnitude of loading rate determined from GRF was compared with subjectively rated body discomfort overall workload.

The GRF is equal in magnitude and opposite in direction to the force that the body exerts on the supporting surface through the foot during manual lifting and is measured by the force plate. Measuring the GRF gives a good measure of musculoskeletal stresses of the subject performing the manual lifting task.

The GRF has three components: Fx, Fy, and Fz. Among these, Fx is in the transverse direction and Fy is along the direction of the motion and Fz is along the vertical direction. Fx and Fy are low in magnitude in comparison to Fz during the lifting task. Fz always thrusts the body upward through feet.

The rate at which the vertical component of the GRF is applied to the body is often measured during lifting. The peak rate of vertical GRF (loading rate) is an indication of the risk of chronic injury due to such activities (Faber et al. 2013; Jena et al. 2017). Loading rate (LR) is defined as the quotient of the peak loading and time to peak loading during human activities and was calculated from the graphical output of Fz.

$$LR = \frac{F_{zmax} - F_{zmin}}{t_2 - t_1} \tag{1}$$

$F_{z\max}$ and $F_{z\min}$ are the peak and lower value of F_z of one lift and (t_2-t_1) is the time span between peak and lower F_z value.

The subjective evaluation was performed by giving a questionnaire to each participant as shown in Fig. 2. The questionnaire contains the body discomfort chart and

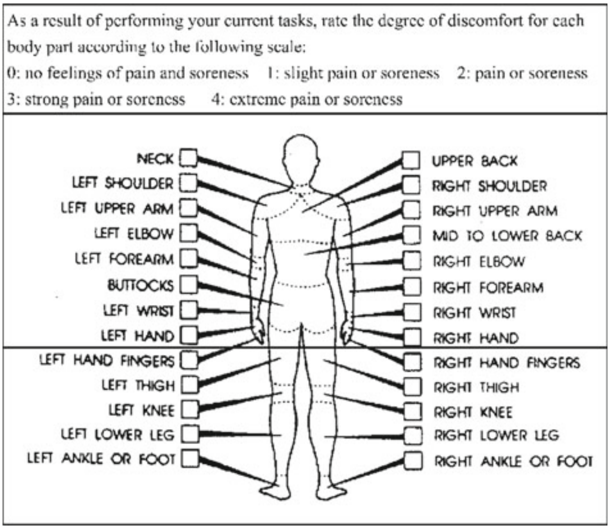


Fig. 2 The body discomfort and overall workload questionnaire (Sauter et al. 1991)

overall workload assessment scale. Each participant was asked to rate the degree of discomfort for each listed body part as a result of performing the type of task being studied. The degree of discomfort is a five-point scale going from no feeling of pain or soreness (0) to extreme pain or soreness (4). After the rating of discomfort, the participant was asked to rate the overall load for the type of task being studied. The workload scale is also a five-point scale with one being very light and five being very hard.

5 Test Procedure

The subjects were properly instructed about the task prior to the actual experimentation and they were also asked to perform 2–3 trials before the acquisition of the data. Each subject was trained to lift a load container from its initial position to the desired destination position in one continuous motion.

It was observed that in the building construction site, especially for handling the concrete mixture, a half-oval-shaped round-opening container was used. This container is made of plastic without any handle. The same container was used in this study. The weight consisting of a concrete mixture (cement, sand, and grit) was placed in the container to ease lifting. Each subject was asked to lift the load from origin to the destination in the asymmetric direction for all trial conditions. A sufficient break was given after each lifting to recover from the fatigue. The Fz was measured after each trial and recorded on a data sheet for further analysis. For each lifting task, GRFs were measured. At the end of each task, the subjects were asked to rate their perceived exertion during lifting as per body discomfort chart (Fig. 2). The loading rate has been compared with subjectively rated body discomfort and overall workload.

6 Response Data Analysis

A full-factorial analysis of variance (ANOVA) was performed to evaluate the subject's response. The results of the statistical analyses in terms of probability value, i.e., *p*-value are given. The statistical significance was considered for $p < 0.05$. The Statistical Package for Social Sciences (SPSS Inc., Chicago, USA, version 16) was used for all statistical analyses.

7 Results and Discussion

Vertical reaction force (Fz) was measured for all 12 subjects for all trials over an experimental period of one minute. One such plot of one subject lifting the weight of 17.5 kg at shoulder height for one minute has been shown in Fig. 3.

In the plot, Fzmin represents the position when the subject was bent for just lifting the container from the original position. In this position, Fzmin is observed to be lower than the bodyweight of the worker. Also, Fz decreases even more with increased vertical distance primarily because of the jerking action required to initiate the lift. However, Fzmax is the position where time span represents the lifting phase and Fz gets larger in magnitude in comparison to body weight and is obtained by measuring the instantaneous force rate from the tangential gradient. From Fig. 3, the value of loading rate (LR) has been found from Eq. (1):

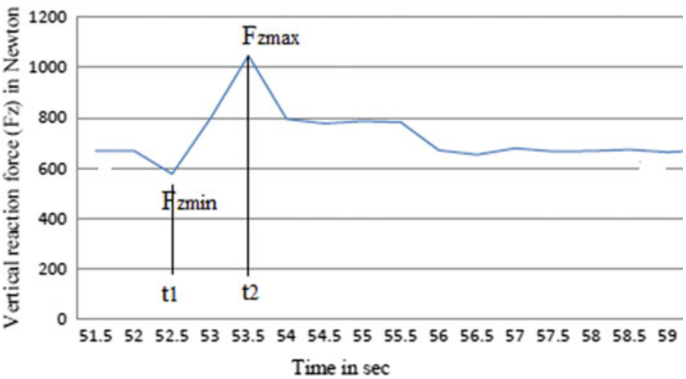
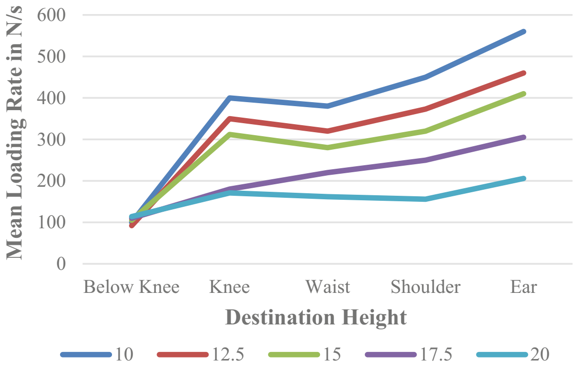


Fig. 3 Vertical reaction force–time graph for subject lifting load of 17.5 kg at shoulder height

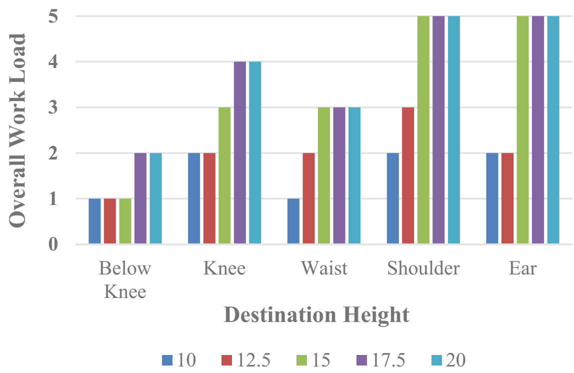
Fig. 4 Mean loading rate plot with variation in weight and destination height



$$LR = \frac{1047 - 578}{53.5 - 52.5} = 469\ \mathrm{N/s}$$

The value of mean loading rate of all 12 subjects has been plotted for various destination heights and weight magnitudes, as shown in Fig. 4. The plot clearly shows that the loading rate increases almost linearly with an increase in the magnitude of weight. Also, the loading rate has been found to increase with an increase in destination height. The loading rate shows no significant change when the destination height is increased from knee level to waist height ($p > 0.05$). However, there has been a definite increase in loading rate when the destination height increases beyond this level to ear level ($p < 0.05$). The increased loading rate signifies an increased exertion to the subjects engaged in dynamic lifting tasks. It has also been seen from the plot that there has been no significant difference in loading rate for lifting 10 kg weight for all destination height ($p > 0.05$). The finding is also found consistent with subjective rating (Fig. 5). Based on the biomechanical and physiological experimental study, Singh et al. (2014) calculated the safe upper limit of loading rate from regression equation as 380 N/sec, for lifting in symmetric posture.

Fig. 5 Mean workload rating plot with variation in weight and destination height



Asymmetrical lifting tasks were generally more difficult than symmetrical lifting tasks. Since the subject had to lift the box and then turn the body through 90° prior to placing the box on the shelf, the cycle time for asymmetrical lifting was longer than for symmetrical lifting. Therefore, the safe upper limit of loading rate suggested by Singh et al. (2014) could not be applicable in the present study.

As mentioned earlier, the cycle times for asymmetrical lifting tasks were longer and subjects lifted the container much more carefully and slowly when lifting asymmetrically than when lifting symmetrically. This caution did result in lower acceptable weights for asymmetrical lifting. Unfortunately, caution on the part of the subjects also resulted in lower accelerations. The combined effects of lower weights and low accelerations are most likely the reason for lower loading rate occurring when loads were lifted asymmetrically. Therefore, based on the subjective rating, the safe limit for loading rate is proposed as 300 N/s when the lift is initiated in an asymmetric direction at 90° to the right of mid-sagittal plane.

Since weight magnitude and destination height significantly affected the loading rate during lifting, different combinations of these parameters have been used to identify the least and the most exerting task conditions. For example, when the weight has increased from 12.5 to 20 kg without altering the vertical distance, the mean loading rate increased by around 38 to 40%. Similarly, when weight is kept constant and the vertical distance is increased from floor to ear level, the loading rate increased by around 26–29%.

The rating of the overall workload was plotted in Fig. 5. It is interesting to find that the mean loading rate and the overall workload rating are well correlated to some extent. Both these responses were based on the concept of increased exertion to the subjects engaged in dynamic lifting tasks. From the subjective rating of discomfort for each body part (Fig. 2), lifting above 15 kg weight at shoulder level causes extreme pain (rating 5) in both the arm and the knee. An increase in weight up to 20 kg *raised* this pain to mid to lower back and right wrist. *For the same weight range from 15 to 20 kg* brings intense *pain* (rating 3) at shoulder level, when weight is lifted to ear level destination.

According to the revised NIOSH lifting equation (Health and Safety Executive (HSE) 2004), the recommended weight limit (RWL) is a weight limit under which nearly all healthy workers could perform over a substantial period of time without increasing the risk of LBP. Although the loading rate and overall workload rating are two variables of different nature, the study showed that they followed a certain consistency in predicting the physical stress as a result of performing lifting tasks. Therefore, the safe limit for various task parameters has to be established to prevent/reduce injuries to workers engaged in lifting tasks. The safe limits have been established in terms of results obtained from loading rate and subjective rating. For example, if the weight is to be lifted from shoulder level, then the weight should not exceed 12.5 kg. Same way, the maximum weight limit of 17.5 kg is to be restricted at waist level.

In the present study, only five levels of rating have been used to determine the overall workload of the subject during a manual lifting task. Borg's RPE (rating of perceived exertion) was not used in the study because it has been felt that the scale might have too many levels for the subject to use correctly. The lower correlation could also be attributed to the fact that the evaluation of an overall workload might be easily contaminated with the manual handling tasks other than the lifting task itself (Table 1).

8 Conclusions

One of the prime beneficiaries of ergonomics is the construction industry, with its physically demanding work. Excessive physical demands beyond one's capabilities may lead to productivity, safety, and health issues in construction. The main objective of the study was to minimize the exertion on the workmen as well as to minimize the risk of subsidence using the most appropriate levels of lifting parameters during lifting tasks performed. The study also determined the safe limits of significant parameters for reducing/preventing any musculoskeletal or chronic injury during lifting. It has been observed that lifting loads with higher vertical distance increase the physiological workloads. The tasks become even more stressful when the heavy load of 17.5 kg is being lifted above the waist level and 15 kg above the shoulder level. Therefore, it is proposed to set the maximum acceptable lifting *weight* to waist level as 17.5 kg and to shoulder level as 15 kg. If the biomechanical or *psychophysical* responses exceed this safe limit, one may experience discomfort and pain that may lead to anxiety about the workload.

Table 1 Rating of body discomfort

Condition	Weight (Kg)	Height	Body part rating
1	10	Below Knee	Left Upper Arm (1), Left Knee (1)
2	10	Knee	Left Knee (1), Right Knee (1)
3	10	Waist	Left Upper Arm(1), Right Upper Arm (1)
4	10	Shoulder	Left Upper Arm(1), Mid to Lower Back (1), Left Knee (1)
5	10	Ear	Left Upper Arm(1), Right Upper Arm (1), Left Elbow (1), Right Wrist (1), Mid to Lower Back(1)
6	12.5	Below Knee	Mid to Lower Back(1)
7	12.5	Knee	Left Shoulder (1), Left Elbow (1), Right Thigh (1)
8	12.5	Waist	Left Upper Arm(1), Mid to Lower Back(1)
9	12.5	Shoulder	Left Shoulder (1), Mid to Lower Back(1)
10	12.5	Ear	Left Elbow (1), Left Wrist (1), Right Wrist (1), Mid to Lower Back(1)
11	15	Below Knee	Left Shoulder (1), Right Shoulder (1), Left Upper Arm (1), Right Upper Arm (1), Left Thigh (1)
12	15	Knee	Left Shoulder (1), Right Shoulder (1), Left Fore Arm (1), Right Fore Arm (1)
13	15	Waist	Left Upper Arm (2), Right Upper Arm (2), Left Knee (2), Right Knee (2)
14	15	Shoulder	Left Upper Arm (2), Right Upper Arm (2), Left Knee (2), Right Knee (2)
15	15	Ear	Left Shoulder (3), Right Shoulder (3), Left Upper Arm (3), Right Upper Arm (3), Mid to Lower Back (3)
16	17.5	Below Knee	Left Upper Arm (2), Right Upper Arm (2), Left Fore Arm (2), Right Fore Arm (2)
17	17.5	Knee	Left Upper Arm (2), Right Upper Arm (2), Mid to Lower Back (2)
18	17.5	Waist	Left Upper Arm (2), Right Upper Arm (2), Mid to Lower Back (2), Left Knee (2), Right Knee (2)
19	17.5	Shoulder	Left Shoulder (1), Right Shoulder (1), Left Upper Arm (2), Right Upper Arm (2), Left Fore Arm (1), Right Fore Arm (1)
20	17.5	Ear	Left Shoulder (3), Right Shoulder (3), Left Upper Arm (3), Right Upper Arm (3), Mid to Lower Back (3)
21	20	Below Knee	Right Knee (1)
22	20	Knee	Left Upper Arm (2), Right Upper Arm (2), Mid to Lower Back (2)
23	20	Waist	Left Fore Arm (2), Right Fore Arm (2), Left Wrist (2), Mid to Lower Back (2)
24	20	Shoulder	Left Upper Arm (4), Right Upper Arm (4), Left Wrist (4), Right Wrist (4), Mid to Lower Back (4)

(continued)

Table 1 (continued)

Condition	Weight (Kg)	Height	Body part rating
25	20	Ear	Left Shoulder (3), Right Shoulder (3)

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Chapter 18
Ergonomic Evaluation of Community Kitchen for Mid-Day Meal Scheme: A Case Study

Pooja Aloorkar, S. M. Qutubuddin, Pooja Rangdal, Saikiran Patil, and Devsudhakar Patil

1 Introduction

Large kitchens are known for a complex work environment, where the workers/cooks are subjected to extreme work environments and a reason of many work-related hazards, injuries and health issues (Kim 2016). Some of the problems related to working in kitchens are musculoskeletal disorders, low back pain and stress (Fazi et al. 2016). Most of the discomfort is due to exposure to harsh heat conditions, exertion of body parts and muscular strain (Shirin Hima Bindu and Reddy 2016). The manual handling of heavy loads, long duration of work in standing postures, pushing, pulling of objects, repetitive movements and awkward postures add up to the discomfort (Rahayu Kamat et al. 2017). It may be due to kitchen workers performing various tasks like cleaning, washing, grinding, cooking, cutting and packaging (Jagannath et al. 2013). In addition to stress, working in a small area, restricted space, time constraints and pressure add up to the discomfort (Rahayu Kamat et al. 2017; Jagannath et al. 2013).

Prolonged working under such extreme conditions may result in chronic injuries to tendons, muscles, ligaments, nerves and blood vessels, which are commonly known as work-related musculoskeletal disorders (WMSDs) (Rahayu Kamat et al. 2017). WMSDs increase the cost of medical services, absenteeism and retraining (Rahayu Kamat et al. 2017). In the food industry, it is important to reduce the risks of musculoskeletal disorders and other associated occupational safety and health concerns, by

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proper application of ergonomic principles and interventions. Another factor in the food industry is that they should follow strict health and hygiene standards. Increased automation in the food industry is accompanied by high noise levels, leading to workers suffering from hearing problems (Sujatha et al. 2015).

Ergonomic approaches are significant in optimum designing of work stations for workers to perform tasks efficiently with little fatigue and discomfort (Shikdar and Al-Hadhrami 2012). Therefore, a detailed ergonomic evaluation of such kitchens is significant to identify the deficiencies in the work and working methods for better understanding in order to effect improvements, productivity, health and safety of the workers. The available literature shows numerous studies conducted on the food industry (Kim 2016; Fazi et al. 2016; Sujatha et al. 2015; Kumari and Kaur 2018), commercial kitchens (Shirin Hima Bindu and Reddy 2016; Kumari 2018), catering workers (Jagannath et al. 2013), cafeteria (Rahayu Kamat et al. 2017) and also industrial canteens and hospital kitchens. The ergonomic issues related to these kitchens and a community kitchen preparing food for thousands of children may be similar. Hence the present study is taken in a community kitchen run by a reputed non-government organization serving the society for the last 17 years.

1.1 Objectives

1. To understand the tasks involved in the community kitchens and to identify the level of musculoskeletal discomfort experienced by the workers.
2. To study the awkward postures of the workers and assess the risks involved using assessment tools like RULA and REBA.

2 Methodology

The methodology used for the current study on the mid-day meals kitchen consists of the following steps:

i. Preliminary survey by observations/questionnaire/interview
ii. Visual analogue scale for measuring discomfort level
iii. Postural analysis by Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA)

Prior to conducting the work, the workers were informed about the purpose of the study, the use of measuring instruments, taking videos/photos of the postures and the observation schedule, and the consent of the owners and workers was obtained.

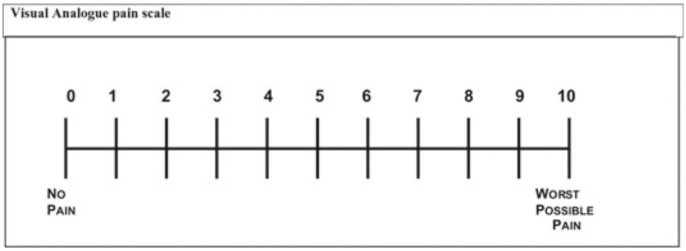

Fig. 1 Visual analogue scale

2.1 Visual Analogue Scale

A visual analogue scale (VAS) is used to determine the overall discomfort/pain level in the workers. A visual analogue scale is a horizontal line, 10 cm in length, with word descriptors at each end. The worker is asked to mark a point on the line as per their feeling of comfort/discomfort. The VAS score is determined by measuring the marked point on the scale from the left end to the point where it is marked. The distance from point zero to the marked point is the result indicators to be processed as a continuous variable (Ghosh 2011).

The advantage of using VAS over other methods is that it gives an overall level of discomfort in the entire body and how the worker feels about the work environment and working methods, rather than giving details of discomfort in each body part separately. For example, the discomfort that a worker feels ranges across a continuum from no pain to extreme pain (Fig. 1).

2.2 Rapid Upper Limb Assessment (RULA)

The tool provides a fast assessment of the posture of the upper limbs, neck and trunk (McAtamney and Corlett 1993). The muscle function and load on the body are also considered in the assessment. The RULA tool generates an action category list with a code that indicates the intervention level necessary to reduce the risk of the worker's discomfort and injury. The tool provides a single score of the entire task which rates the posture, movement and force required. The risk is calculated and gives a score of 1 (low) to 7 (high). The scores are categorized into four action levels that give a recommendation when a risk control action should be initiated (Syed Ali et al. 2018).

2.3 Rapid Entire Body Assessment (REBA)

This method is used for assessing the postures of the entire body. For assessment of postures using REBA the information about the body posture, force, the type of action or movement, repetition, and coupling is collected. The final REBA score generated gives recommendations on the level of risk and required action levels (Hignett and McAtamney 2000). The risk score increases as the postures move away from the neutral position. Various posture combinations are converted into a particular score by using the table which represents the level of musculoskeletal risk. The scores are then grouped into five action levels that indicate the risk levels from no risk to very high risk and the action is taken accordingly.

2.4 Mid-Day Meals Kitchen

The kitchen of the mid-day meal programme of a well-known NGO was selected for the study. The NGO provides nutritious meals to over 15,000 children covering 72 schools in and around Kalaburagi. The meals are prepared in well-equipped kitchens and the food is packed in stainless steel containers for distribution to schools. The food is served by teachers and volunteers to the school children.

The work starts at 4 am in the morning and runs up to 11 am. The unit has five boilers for cooking rice and one for boiling milk, and one boiler for cooking *sambar*. One boiler is kept as a standby in case of any breakdown. Each boiler has a capacity of 75 kg raw rice and the *sambar* boiler has a capacity of 200 kg. The boilers are utilized continuously and the cooking is done in four rounds. In each round, 375 kg of rice is cooked, totalling approximately 14 quintals each day. The *sambar* is cooked in 2 rounds of 200 kg in each round. The cooking time for one round of rice in five boilers is approximately 45–50 min.

The unit works in two schedules. The first schedule starts with boiling milk and preparing breakfast. The food is packed in boxes of different capacities, (100, 50 and 25 students) and at 7 am the breakfast and milk are transported to the schools located around the city and rural areas. Each student is served breakfast and 100 ml of milk. Every day 1200–1400 L of milk and approximately 800 kg of breakfast food is prepared.

Once the breakfast is finished, the workers start the next schedule for cooking lunch. All the utensils and boilers are cleaned and washed prior to the start of the next schedule. The typical menu for lunch is *rice and sambar* for 4 days, *Alu bhath/bisi-bele bhath/Pulav/Pongal* for the remaining two days. On Saturdays the schools run for half-day, so only breakfast is prepared. After preparing the lunch in about four rounds, the food is simultaneously packed in boxes and transported to schools. At around 11 am, all the cooked food is dispatched to the schools. In the evening from 3 to 7 pm, a few workers clean the vegetables and keep ready other materials for the next day's cooking.

2.5 *Preliminary Observations and Study*

A preliminary study of the kitchen was carried out through observation, discussion and a simple questionnaire to understand the prevailing problems relating to postures, MSDs, noise, heat and humidity (Table 1). It has been found that the risks of MSDs exist for extreme postures. Almost in all workplaces, the workers adopted awkward postures while doing work. The noise level is reported to be moderate at some places and high in washing and cooking areas. Time pressure is high because the food has to be ready by the allowed time for transporting to the various schools. Illumination levels were also low at some places. Based on the initial observations, the awkward postures were analysed at all workplaces using the assessment tools RULA and REBA.

The workers' demographic data are collected (Table 2). The mean age of male workers is 34.73 (±8.44) and the mean age of female workers is 34.94 (±9.07). The mean height, weight and experience are also noted. The average experience of male workers is 9.42 years (SD 3.91) and the average experience of female workers is 9.12 years with (SD 4.05). The duration of work is 7–9 h depending on the tasks assigned. The minimum age of the workers is 21 and the maximum age is 52 years. Similarly, the minimum experience is 1 year and the maximum experience is 15 years in this unit.

The distribution of work activities among male and female workers and the nature of work is given in Table 3. All male workers perform activities such as food prepara-

Table 1 Worker concern on different ergonomic issues

Occupation	*A	*B	*C	*D	*E	*F	*G
Kitchen workers	Moderate to High	Moderate to High	Moderate *High near cooking area	Moderate	Moderate to High	Moderate	Moderate

* A—musculoskeletal discomfort, * B—awkward postures, * C—Heat, * D—Noise, * E—time pressure, * F—health & Hygiene, * G—any other (dust, vibration, illumination, ventilation)

Table 2 Workers' demographic data

Variables	Male	Female
	Average (SD)	Average (SD)
Age (year)	34.73 (8.44)	34.94 (9.07)
Height (cm)	160.59 (7.42)	155.75 (4.10)
Weight (kg)	60.17 (7.81)	54.21 (5.92)
Experience (year)	9.42 (3.91)	9.12 (4.05)
Duration of work (hour)	7–9	7–9
Working days	6	6

Table 3 Distribution of work activities among kitchen workers

Nature of work	No. of workers (n = 42)	
	Male (n = 22)	Female (n = 20)
Food preparation/cooking	06 (27.27%)	–
Boiler maintenance	02 (9.09%)	–
Distribution/loader	10 (45.45%)	–
Packing food	–	6 (30%)
Cleaning, washing	–	14 (70%)
Office work/procurement	04 (18.18%)	–

tion (27.27%), boiler maintenance (9.09%), distribution/loading (45.45%) and office work (18.18%). The female workers are assigned the task of packing food (30%) and cleaning, washing and preparation (70%).

The food preparation activities include cooking food and all associated activities. As shown in Table 3, the duties are assigned to each employee. But during the course of work, the workers perform many different tasks according to the need of the situation. More number of workers are required in the washing and cleaning section as all the utensils, food boxes and boilers have to be cleaned to maintain the necessary cleanliness and hygiene.

3 Results and Discussion

3.1 Visual Analogue Scale Score

The VAS score gave an overall discomfort level in the entire body of the workers. The responses obtained from the VAS show an overall score of 5.6 with a standard deviation of 0.781. This score indicates a high intensity of discomfort and pain among the kitchen workers. A high VAS score is reported in workers of increasing ages. ANOVA values between VAS score and experience showed $F = 29.327$ and $p < 0.001$. This may be due to the fact that over the years these workers are exposed to high stress and heavy handling jobs.

The activity-wise average VAS score is given in Table 4. The VAS score is compared with the RULA score obtained by assessing awkward postures in each activity. The average RULA score for each activity and the overall RULA score is 6.08 with SD 0.641.

ANOVA test results show f-ratio value is 5.65773. The p-value is 0.034852. The result is significant at $p < 0.05$. The average visual analogue scale score for various activities obtained from the responses of the workers performing different activities and the average scores of RULA assessment is shown. Maximum discomfort is reported by the workers in the cooking area according to RULA analysis with a discomfort score of 7, followed by workers doing stirring and cooking sambar (score

Table 4 Activity-wise VAS and RULA scores

Task/Activities	Average VAS score	Average RULA score
Cut vegetables	5.7	5.4
Washing	5.2	6.1
Cooking rice	6.7	7
Stirring food	6.3	6.8
Moving food to packing	4.5	5.9
Packing food	4.9	5.3
Washing containers	5.9	6.1

6.8). This is due to the fact that the workers have to perform the activities working above the shoulders and continuously standing. Another issue is the heat from the kitchen as the workers are very close without any protection from heat stress. The VAS discomfort score also indicated cooking activity as the most difficult (average score 6.7) task followed by stirring the food (average score 6.3), as the workers continuously stand near the boiler.

3.2 Postural Analysis

About 32 workers' postures were selected for RULA and REBA analysis. The results of RULA (Table 5) indicate that 37.5% of the postures fall under the high-risk category and are subject to immediate change. As many as 28.15% of postures fall in the medium-risk category requiring further investigation and change soon. The low-risk category is shown to be in 25% of postures, while 9.37 postures require no change and are acceptable. The results of RULA are in line with some of the earlier reported by Fazi et al. (2016); Rahayu Kamat et al. 2017; Syed Ali et al. 2018).

The results of REBA analysis highlight 21.87% of postures in the very high-risk category and 31.25% postures in the high-risk category. Here the risks are due to working in extreme conditions in awkward postures. The workers at the boilers

Table 5 RULA action levels and percentage of workers in each category

RULA	1–2	3–4	5–6	7
Level of risk	Negligible	Low	Medium	High
Required action	Not required	Change may be needed	Investigate change soon	Change immediately
No. of workers	3	8	9	12
% of workers	9.37	25.00	28.15	37.50

Table 6 REBA action levels and percentage of workers in each category

REBA	1	2–3	4–7	8–10	11 +
Level of Risk	Negligible	Low	Medium	High	Very High
Required Action	No action required	Change may be needed	Investigate change soon	Investigate and change	Change immediately
No of workers	0	5	8	10	7
% of workers	0	15.62	25.00	31.25	21.87

for loading and unloading, the cleaning and some packing workers reported high REBA scores. To reduce the risks and prevalence of discomfort, these postures should be attended first and changed immediately. Postures in the medium and low risks category are 25% and 15.62%, respectively. Earlier REBA assessment studies done on workers by Rahayu Kamat et al. (2017); Syed Ali et al. (2018) indicated similar results. Similar results are reported by Jagadish et al. (2018) in a study on small-scale industries (Table 6).

3.3 Work Environment

Another significant contributor to ergonomic assessment is the work environment. Different environment parameters were measured in the kitchen by appropriate measuring instruments. Five readings were taken at different points in the kitchen. The noise measured (LUTRON SL-4023SD) exceeded more than the allowable limit of exposure (90 dB) at two places near the boilers and the washing and packing section. Illumination levels were also measured (LUTRON lux meter model LX-1102 SD). Overall the illumination was low (110–213 lx) at many places. The recommended value of illumination for kitchens is about 300–500 lx (Kumari and Kaur 2018). The temperature and humidity were measured (HTC HD-304 Temperature meter). As Kalaburagi has day temperatures varying from about 26 to 44° during the year, the measured values (28.7 °C–34.4 °C) were during the month of October–November.

3.4 Workstation Redesign

To illustrate the nature of ergonomic interventions that can improve worker performance and reduce the risk of musculoskeletal disorders, the activity of cutting vegetables is selected. Around 3–4 workers are involved in cutting and preparing vegetables for use in cooking. The existing workplace is just squatting on the floor to perform

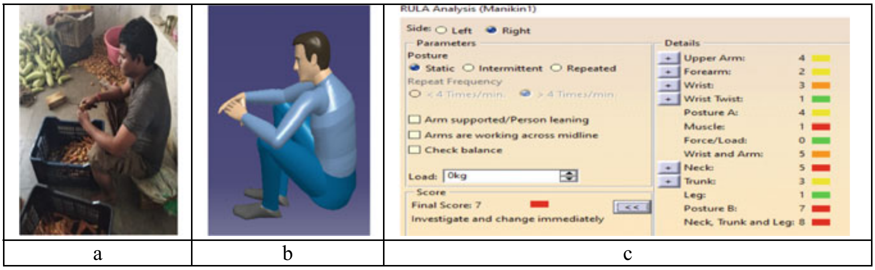

Fig. 2 Existing workplace and posture (**a**), CATIA model (**b**) and RULA analysis score (**c**) for vegetable cutting activity

the task. The workers adapt several awkward postures during the work according to their comfort. The average VAS score for this activity was 5.7 and the average RULA score was 5.4. One of the worst postures was captured through the photograph (Fig. 2a) and was modeled in CATIA software (Fig. 2b). The same posture was analysed using the RULA assessment tool option in CATIA, which indicated a high risk with a score of 7 (Fig. 2c).

The existing workstation was redesigned by providing a comfortable sitting posture to the workers. The worktable layout is arranged according to the principles of motion economy. The worker is provided with a low back support adjustable chair so that he can work in a comfortable posture. Anthropometry measurements and design of workstation principles (Shikdar and Al-Hadhrami 2012; Kumari 2018; Qutubuddin et al. 2012) were followed. The new workstation design and the human manikin posture were analysed using the RULA tool. The final score of the RULA assessment was 2, indicating a low risk. Due to the changed posture of the worker, the risks of musculoskeletal disorders are minimized and worker comfort and safety increased (Fig. 3).

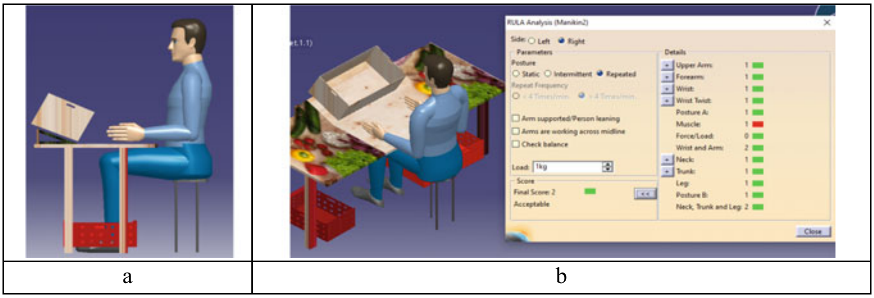

Fig. 3 Redesign workstation for vegetable cutting (**a**) and RULA analysis score (**b**)

4 Conclusion

The present study is mainly focused on the ergonomic evaluation of the kitchen for mid-day meal scheme. The study is a part of planned series in the field of the food production industry, and highlights the prevalence of MSDs and ergonomic issues. The overall result of VAS indicated a discomfort score of 5.6. The results of RULA analysis showed 37.50% of workers are at high risk and need immediate attention to change working postures. Similar results were obtained from REBA analysis indicating 31.25% postures in high risk and 21.87% in very high risk. It can be concluded that fatigue, discomfort, and prevalence of MSDs are influenced by postures and work activities. Workers report heavy lifting of loads intermittently.

Overall the study finds certain ergonomic deficiencies, layout problems, lack of personnel protective equipment (PPEs) and work station design as reasons for high risks in postures and discomfort. It is suggested to use height adjustable hydraulic operated pallet trucks for movement of food grains from stores and also cooked food from the boiler to packing areas. It becomes more significant to reduce the risks by having proper postural modifications, workstation design, training, reducing the loaded weights and rest breaks.

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Chapter 19
Ergonomic Evaluation of Rubber Tapping Workers Using Postural Ergonomic Risk Assessment

Abi Varghese and Vinay V. Panicker

1 Introduction

The rubber tapping is the most demanding skilled agricultural operation in most of the Asian countries like Thailand, Indonesia, Malaysia, India and 90% of the global natural rubber production is from Asia. The musculoskeletal disorders (MSDs) among the rubber tapping workers are high due to cyclic workload, awkward posture, etc. A postural assessment conducted among the rubber tapping workers of Southern Thailand using the Rapid Upper Limb Assessment (RULA) method had reported that one-fourth of the rubber tappers have a RULA score of 4. Hence, a detailed investigation about the body posture of the rubber tappers is necessary and analysis about the change of posture (Meksawi et al. 2012).

A similar study was conducted to evaluate the Carpal Tunnel Syndrome (CTS) among the Thailand rubber tappers using the Boston Carpal Tunnel Syndrome Questionnaire and RULA method. The result found that high wrist flexion and ulnar deviation during repetitive tapping cause CTS. Even though the RULA Score for the wrist flexion was varying between 1 and 3, which is an acceptable posture (Pramchoo et al. 2018a). As an extension to previous research, an ergonomically designed rubber tapping knife is used to improve the CTS among the rubber tappers. However, it is reported that there is no significant difference in wrist flexion among ergonomic and traditional tapping knife users (Pramchoo et al. 2018b).

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Another study was conducted among Srilankan rubber tappers using Quick Exposure Check (QEC) instrument. This research using QEC indicates that shoulder (96.7%), back (94.2) and neck (83.3%) have the highest exposure to ergonomic stress (Stankevitz et al. 2016). Similarly, another study was conducted among the rubber tappers in Malaysia using Nordic Musculoskeletal Questionnaire, and the work reveals that 74.4% of the rubber tappers have a prevalence of MSDs in lower back (Doi et al. 2007; Udom et al. 2016). In addition, few researchers have investigated the prevalence of lower back pain among the Thai rubber tappers and identified that body mass index, primary education and tapping below the knee level are the main reason (Udom et al. 2018). Another poster analysis tool called Ovako Working Posture Analyzing System (OWAS) has been used among the Colombian rubber tapping workers and found that posture score for rubber tapping activities was 4, which calls for an immediate corrective measure (Velásquez et al. 2016).

Most of the ergonomic studies include various posture analysis tool like OWAS, RULA and QEC and some of the literature have further conducted a statistical analysis using various surveys. It is also reported that each of these tools has few limitations. OWAS is a primitive body posture analysis tool, having four digital code for defining various parameters includes back, arms, legs (84 postures) and its corresponding loads (Karhu et al. 1977). The wide range of body postures in OWAS makes misperception to identify accurate body posture and ergonomic stress (Keyserling 1986). RULA is the most useful body poster analysis tool to evaluate work-related upper body disorders (McAtamney and Corlett 1993). It is observed that the rubber tappers having CTS had the RULA score varying from 1 to 3, which is an acceptable level (Pramchoo et al. 2018a). Most of the ergonomics analysis tools are not considering the cyclic work. However, in the present study, the posture analysis of rubber tappers is conducted. Rubber tapping is a monotonous task that involves repetitive work, and each tapper has to cut 300 to 1000 rubber trees every day (Boonphadh 2008). Postural Ergonomic Risk Assessment (PERA), a posture analysis tool which is suitable to evaluate short cyclic work and also help to recognize the source of risk of the workers is applied (Chander and Cavatorta 2017).

The aim of this study is as follows:

- Identify the rubber tapping operations and divide into different work elements.
- Evaluate the percentage of cyclic time and the force required for each task.
- Apply the PERA for posture analysis among the rubber tappers.

2 Materials and Methods

A. *Study Population*

The study was conducted among the rubber tappers in Kottayam, situated in middle Kerala, India. Ten rubber tappers (nine male and one female) were selected for the study. The objective of the study and the data collection methods was informed to all workers, and oral consent was obtained before data were collected. The inclusion criteria for the selected rubber tappers includes the worker (a) should be a regular tapper, (b) should have a minimum of one-year experience (c) should have an age of 18 years or above.

B. *Postural Ergonomic Risk Assessment (PERA)*

The major evaluation criteria for PERA (Chander and Cavatorta 2017) in rubber tapping process involves.

- Working posture of the rubber tappers
- Force required for tapping
- Duration of each task involved in rubber tapping

The major steps involved for applying PERA are as follows (Chander and Cavatorta 2017);

1. **Work task in rubber tapping**: Based on the distinct posture involved in rubber tapping, divide the work cyclic into different tasks.
2. **Posture for each work task**: Identify the posture of each rubber tapper in each work task
3. **Force applied in each work task**: Calculate the force applied for each work task
4. **Time interval for each work task**: Evaluate the time interval of each work task involved in rubber tapping.
5. **PERA Score**: Categorize the posture, time and force into different risk level.

- Assign the score 1, 2 and 3 for different risk level low, medium and high.
- Calculate each work task score by multiplying each parameter score Work Task Score T_i = (Posture Score)$_i$ × (Force Score)$_i$ × (Duration)$_i$
- Calculate the overall average work cycle score

Overall work cyclic Score A, $= \frac{Ti}{n}$
Where, n = no of work task

(1) *Work task in rubber tapping:* The rubber tapping is the primary step in the rubber harvesting process. Based on the different posture, the cyclic work during the rubber tapping is divided into four tasks and are shown in Figs. 1 and 2.

(2) *Posture for each work task:* The posture of rubber tappers in each work task should be identified and categorized into a low, medium and high risk. Based on the risk level, the score 1, 2 and 3 are assigned to low, medium and high risk, respectively. The detailed body posture and the risk level are tabulated in Table 1.

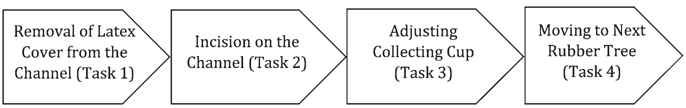

Fig. 1 Flow Chart of various work task in rubber tapping

Fig. 2 Various work task in rubber tapping (**a**) Removal of latex cover from the channel (**b**) Incision on the channel (**c**) Adjusting the collecting cup (**d**) Moving to next rubber tree

(3) *Force applied in each work task:* The physical effort exerted by the rubber tapping workers should be identified and sorted as low, medium and high risk. The physical effort which is not visible like handling of lightweights is included in the low-risk category. The smooth and controlled operations, operations with both hands used, not a heavy operation are encompassed in a medium risk. The

Table 1 Classification of body posture and risk level during rubber tapping (Chander and Cavatorta 2017)

	Trunk-Forward bending	Shoulder—Flexion	Head and neck-Forward bending	Elbow Flexion
Low Risk (Score 1)	0°–20°	0°–20°	0°–25°	0°–20°
Medium Risk (Score 2)	20°–60°	20°–60°	25°–40°	20°–60°
High Risk (Score 3)	>60°	>60°	>40°	>60°

Table 2 Classification of cyclic time during rubber tapping (Chander and Cavatorta 2017)

	Low risk (score 1)	**Medium risk (score 2)**	**High risk (score 3)**
Percentage of the cyclic time for each work task	0%–10%	10%–20%	>20%–10%

Table 3 PERA overall work cycle score (Chander and Cavatorta 2017)

Overall score	Classification of risk level	Recommended actions
$A < 4$	Low Risk	Acceptable; No action is necessary
$4 \leq A \geq 7$	Possible Risk	Further Investigation by a more refined method
$A \geq 7$	High Risk	Not acceptable; Corrective action is necessary

operations which are clearly visible such as vibration from power tools, heavy hammering, impact or shock from heavy machinery are counted in high risks.

(4) *Time interval for each work task:* The time interval required for each work task should be tabulated and the percentage duration of each work task with respect to the cyclic time is to be calculated. The duration of the work is categorized into low, medium and high risk based on the percentage of cyclic time. Each risk level carries a score of 1, 2 and 3 for low, medium and high risk, respectively, and the detailed classification is tabulated in Table 2.

(5) *PERA Score:* The overall work cycle scores are categorized into three levels and listed in Table 3.

3 Result and Discussion

A. *Posture for each work task*

The major body parts involved in the tapping operation are shoulder and elbow, for the first two tasks. The angle measurement for both the cases is more than 60°.

Fig. 3 Posture of each work task in rubber tapping

Table 4 Score of posture for each work task

	TASK 1	TASK 2	TASK 3	TASK 4
SCORE	3	3	3	1

Therefore, task 1 and 2 come under the third category. In task 3, trunk and shoulders are the major body parts involved, and the angle measurement for both the cases are also greater than 60°. So, the score for task 3 was also noted as 3. In task 4, rubber tappers are moving from one tree to the next tree. Hence it was considered as 'low risk' category. Figure 3 shows the posture and angle measurement of each task, and score for each task is tabulated in Table 4.

B. *Force applied in each work task in rubber tapping*

The force required for all tasks expects the second task is considered as low-risk because physical effort exerted in each task is negligible. In task 2, the force required for making an incision in the bark of the rubber tree is calculated using a strain gauge. The force required for a tapping rubber tree is found to be less than 100 N, and the movement of the hand is smooth and controlled during tapping. So, task 2 is considered as medium risk.

III. *Time interval for each work task in rubber tapping*

The time required for each work task is evaluated and the percentage of cyclic time is calculated. Based on the percentage of cyclic time, corresponding score for each task was tabulated and shown in Table 5. The result indicates that the rubber tapper spends most of the time for making incision on the bark of the rubber tree.

IV. *PERA Analysis*

The overall work task scores for each rubber tapper are shown in Table 6. It is found that each rubber tapper has the PERA score of greater than 8, which is recommended for high risk. The score also helps to identify the critical task to be the second task of making incision on the channel among each work tasks.

Table 5 Percentage of cyclic time and corresponding score

Name	Time Durtion (%)				Score			
	Task 1	Task 2	Task 3	Task 4	Task 1	Task 2	Task 3	Task 4
Subject 1	21	48	12	18	3	3	2	2
Subject 2	17	50	13	21	2	3	2	3
Subject 3	20	40	17	23	2	3	2	3
Subject 4	28	41	14	17	3	3	2	2
Subject 5	19	48	13	19	2	3	2	2
Subject 6	18	50	12	21	2	3	2	3
Subject 7	19	52	13	16	2	3	2	2
Subject 8	21	45	17	17	3	3	2	2
Subject 9	16	52	13	19	2	3	2	2
Subject 10	17	48	17	17	2	3	2	2

Table 6 Overall score of the work cycle

Final score						Recommended action
Name	Task 1	Task 2	Task 3	Task 4	Work task score	
Subject 1	9	18	6	2	8.75	Not acceptable, Corrective action is necessary
Subject 2	6	18	6	3	8.25	
Subject 3	6	18	6	3	8.25	
Subject 4	9	18	6	2	8.75	
Subject 5	6	18	6	2	8	
Subject 6	6	18	6	3	8.25	
Subject 7	6	18	6	2	8	
Subject 8	9	18	6	2	8.75	
Subject 9	6	18	6	2	8	
Subject 10	6	18	6	2	8	

4 Conclusion

Rubber tapping is the first and foremost step in natural rubber processing. The rubber tapping involves repetitive motion and contributing high ergonomic risk to various body parts includes elbow, shoulder and trunk. Most of the posture analysis tool like OWAS, RULA, REBA etc. are not considering the cyclic work. PERA is a posture analysis tool to evaluate short cyclic work, which is suitable for the rubber tapping process.

In PERA, the work cycle involved in rubber tapping is divided into different tasks based on the distant postures. The posture of the rubber tappers, the force involved during tapping and duration of each work task is evaluated. Based on the evaluation criteria, each work task is categoried into “low risk”, “medium risk” and “high risk” and score 1, 2 and 3 are assigned. The overall PERA score is identified as 8 or more for the work cycle, which is corresponding to a level of ‘high risk’. Therefore, the body postures resulted by the tapping work are not acceptable and corrective actions are necessary. Thus the preventative measures are to be implemented in order to prevent bad working condition.

Throughout the research, it is identified that this study has some limitations. First, the rubber tappers selected for this study include workers as well as farmers. Among farmers, they took a long time for tapping, to improve productivity. Second, the posture for each work task by each rubber tappers are varying in different tapping height.

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Chapter 20
Ergonomics in DIY Learning: Comparative Study of Children's STEM Education Kits Assembling Experience

Gurmeet Singh and Sanjay Gupta

1 Introduction

Do-it-yourself (DIY) learning has gained the attention of various stakeholders in K-12 science, technology, engineering and mathematics (STEM) education. For this, various construction and assembling kits are available in the market. Different Indian brands have emerged in recent years in this domain. DIY learning and hands-on STEM learning with kits are known as 'making', 'building' and 'experiential learning' also.

Making can help to realize the goals of K-12 education as it promotes curiosity about how things work and how to improve them (Kalil et al. 2013). Hands-on learning help pupils examine understanding through reflection, evaluation and reconstruction (Ting and Tai 2020). Further, such learning stimulates pupils' interests in academics (Holstermann et al. 2010).

Regardless of substantial work in this domain, designers' and parents' understanding of a child's experience of hands-on learning setting is very poor (Chu et al. 2017). Although most of such learning is practiced in summer camps, hobby classes and craft events, schools also have started implementing hands-on practical learning in their classrooms. DIY kits enhance ease of understanding, encourage students and take benefit of existing real-life resources in and around schools and homes (Mäkelä and Vellonen 2018).

Learners' engagement is improved when they experience a learning activity as enjoyable and pleasant. So, the design of DIY STEM education kits is critical and the ergonomic considerations decide learners' experiences. Negative experiences in DIY kit assembling may cause fatigue, disinterest and even strong disliking for the subject at hand and academics in general. So, identification and representation of students' kit assembling experiences are crucial for realizing the goals of hands-on learning, designing better learning products and the overall success of the business

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of learning toys and kits. Now, ergonomics is being manipulated for the usability and safety of systems that people use and the quality experience of users in interaction with the system (Canina et al. 2020). Thus, ergonomics confirms both the well-being of the user and the working of the system.

Even after the increasing concern in DIY learning methods in mainstream education, no major study is available on students' learning experience with DIY STEM kits (Mäkelä and Vellonen 2018). This study was conducted to understand users' STEM education kit assembling experiences in context with ergonomic considerations and features by comparing two similar kits of the human hand (bionic hand and mechanical hand) designed and manufactured by two different Indian brands.

We highlight concerns that may inform designers and parents to design and select the right DIY STEM kits in the future. Our work contributes significantly as there is a lack of research on students' STEM education kit assembly experiences. The quality of students' kit assembling experiences displayed positive relationships with their interest in the respective activities, topics and further learning on the same. For that reason, this paper discusses in favor of considering ergonomic factors in designing DIY STEM education kits to make them playful and encouraging during assembly.

2 Literature Review

Hands-on learning through construction kits improve pupils' understanding along with fun and pleasure and encourage them for active engagement (Somyürek 2014). 'Making' turns the learning into an enjoyable, engaging and effective act (Giannakos et al. 2017a) and leads to more inspired learners with a better understanding of the subject at hand (Stager 2005). Research shows that products involving playful exploration sustain active participation as compared to those lacking it (Bischof et al. 2016).

Some activities bridge the gap between classroom learning and real-life settings, but they rarely include average and low performing students in their structure (Bridgeland et al. 2008). Design-based ergonomic intervention may address such shortcomings by making the learning experience accessible, usable and effective (Bennett et al. 2013). As making involves fun and enjoyment (Buechley and Perner-Wilson 2012), right hands-on experiences turn learners into creators from just being users (Vandevelde et al. 2016). Learners reported using their DIY learning in their future career and profession and the research also indicates that the integration of DIY STEM activities may develop pupils' interest in pursuing STEM-related professions (Baran et al. 2016).

While safe, easy to use, pleasant and instantly understandable products succeed in the market; making these aspects visible at the time of buying is also critical (Tosi 2020a). Some studies demanded to speed up research on the maker movement by establishing collaboration among educators, researchers, students, policymakers, and

Table 1 Study sample distribution

Age (Years)	Participants (Number)	Boys	Girls	Class 6	Class 7
10	23	16	7	13	10
11	26	15	11	11	15
12	19	14	5	11	8

designers to apply investigation approaches and metrics for exhaustive studies (Giannakos et al. 2017b, 2015). As STEM education kits are assembled using an instruction manual provided with them, it is important to make them intuitive and usable with the right affordances. According to the ISO standards (ISO 9241–11:2018(en)), 'usability is an extension to use a product or service within a system, by specific users to achieve specific objectives with effectiveness, efficiency and satisfaction in a given context of use (Tosi 2020b)'. As the user anthropometric characteristics, capabilities and limitations depend on age and sex and may affect their readiness and attitude in using products (Tosi 2020c), ergonomic considerations find a central role in DIY STEM education products.

Designers can use evidence on how ergonomics and design choices affect students' moods and experiences while assembling DIY STEM education kits. So, identification of user experience is crucial to design better products (Vastenburg et al. 2007). User experience embodies emotions, perceptions and reactions of the user while interacting with the product. Thus, it is an aspect of the design that focuses on user characteristics and needs (Brischetto 2020).

3 Study

3.1 Subjects

68 students of 10–12 years of age who were enrolled in different schools of Delhi-NCR participated in the study. The participants were class 6th and 7th students practicing in-school or out of school hands-on learning with DIY STEM education kits for at least one year. The mean age of the sample was 10.9 years with a standard deviation of 0.78. A total of 45 boys and 23 girls participated in this study out of which 35 and 33 students were from classes 6 and 7, respectively. The sample distribution is shown in Table 1.

3.2 Materials

To identify and represent students' STEM education kits assembling experiences, this study was done using two similar DIY STEM kits (bionic hand and mechanical hand) designed to learn about anatomy and working of the human hand. The final products of these kits are shown in Fig. 1. These kits are manufactured by two major Indian brands for the 8–14 year age group students. Table 2 shows details about parts of these kits. Direct observations were taken in respondents' natural settings during the kit assembly and students' were asked to fill up a printed questionnaire to record their responses after the kit assembly was done. The questionnaire had 12

Fig. 1 Final products of the mechanical hand kit and the bionic hand kit

Table 2 Kits and parts details

Kit Details	Bionic Hand Kit	Mechanical Hand Kit
Major materials	MDF (medium-density fiberboard) and paper	Engineered Wood
No. of parts	60+	300+
Smallest part size (h, l, w) (cm)	1, 0.5, 0.1	0.75, 1.5, 0.2
Biggest part size (h, l, w) (cm)	30, 12, 0.4	18, 16, 0.3
Final product size (h, l, w) (cm)	45, 18, 6	29, 16, 15
Final product weight (g)	120	250
Types of joineries	Velcro, sticker, thread tying	Fitting slots with rubber bands
Marked age group	10–12 years	8–14 years

objective-type questions including one illustration of a pictorial mood representation instrument (Vastenburg et al. 2011; Desmet et al. 2012).

3.3 Purpose

The purpose of this study is as follows:

(1) To identify and compare students' DIY STEM education kits assembling experience.

(2) To analyze the correlation between students' kit assembling experiences and their engagement, and attitudes for the subject at hand.

(3) To identify and analyze correlation between ergonomic considerations in the design of kits and students' assembly time, injuries, engagement and overall mood while assembling the kit.

3.4 Study Procedure

The study was conducted in a natural classroom setting in four schools of Delhi-NCR in presence of their regular instructors. These classes were part of after school engineering clubs for DIY hands-on STEM learning. Students worked individually on their kits using the instruction manuals provided along with the kits. 34 students from two schools were given the bionic hand kit and the rest 34 students from the other two schools were given the mechanical hand kit. Following steps were taken to execute the study:

Step 1: First, STEM kit boxes were given to students by their regular instructors.

Step 2: Students were asked to start assembling the kit.

Step 3: To record unarticulated behavior, direct observations were taken by the authors during this event. The total time taken by individual students to complete the kit assembly was also noted.

Step 4: After completion of the kit assembly, students were informed about the other similar kit for hand anatomy (without showing any product or pictures) and they were given objective questionnaires to record their assembly experiences.

Step 5: Direct observations and questionnaire responses were analyzed to identify and represent students' kit assembly experiences, the co-relation between their experiences and engagement, attitudes, ergonomic considerations in the design of kits, students' kit assembly time, injuries and engagement while assembling the kits.

4 Results and Discussion

A pictorial mood representation instrument (Vastenburg et al. 2011; Desmet et al. 2012) was used to measure students' overall experience of kit assembly. The character expressions in this instrument are superimposed on two axes of valence (pleasure–displeasure) and arousal (high energy–low energy).

The minimum and maximum time taken to assemble the bionic hand kit was 55 min and 120 min, respectively, while that for the mechanical hand kit was 75 min and 140 min, respectively. One and three students couldn't complete the bionic hand kit and mechanical hand kit within 120 min and 140 min respectively. Excluding them, the average assembly time for the bionic hand kit and mechanical hand kit was 83.6 min and 112.7 min, respectively. Girls took an average time of 88.7 min to complete the bionic hand kit as compared to 80.7 min that of boys. The average mechanical hand kit assembly time taken by girls was 111.1 min as compared to 113.4 min for boys.

The average time taken by participants who reported to be irritated and tensed during the bionic hand kit and mechanical hand kit was 100.3 min and 123.3 min respectively while that was 72.6 min and 101.5 min for the students who reported to be excited and cheerful during the assembly. Overall, 50% of students felt excited and cheerful and 38.2% felt irritated and tensed while assembling the bionic hand kit while that was 38.2% and 35.2%, respectively, for the mechanical hand kit. The negative experience rate was higher among students who faced difficulty to assemble the kits and consequently took more time to complete the task or failed to do so. Such students were observed with unpleasant facial expressions, struggling to fit parts and repeated trials to fix parts at the wrong places. Thus, intuitiveness and the right affordances are crucial in the design of STEM education kits. Few of the excited and cheerful students were seen assembling similar parts (fingers) even without referring to the instruction manual after the assembly of the first finger (part). As the task success and experience quality regulate students' deep-down motivation (Krapp 2005), ergonomic interventions may be manipulated to achieve the same (Canina et al. 2020).

Further, students' experience comprises of the effect of usability, utility and the emotional influence in the interaction (kit assembly) and retention of activity after completing the assembly (Brischetto 2020). A total of 33.8% of students reported to get mild hand injuries, 41.1% of learners showed interest to explore more to deepen their understanding of human hand anatomy, only 16.1% of students were interested to assemble the other hand kit while 64.7% of them reported the final product not fitting properly in their hands. In response to the sizes of the parts, 32.3% of students reported the parts to be inappropriate to handle with their hands. The overall kit assembly experience of students is illustrated in Fig. 2.

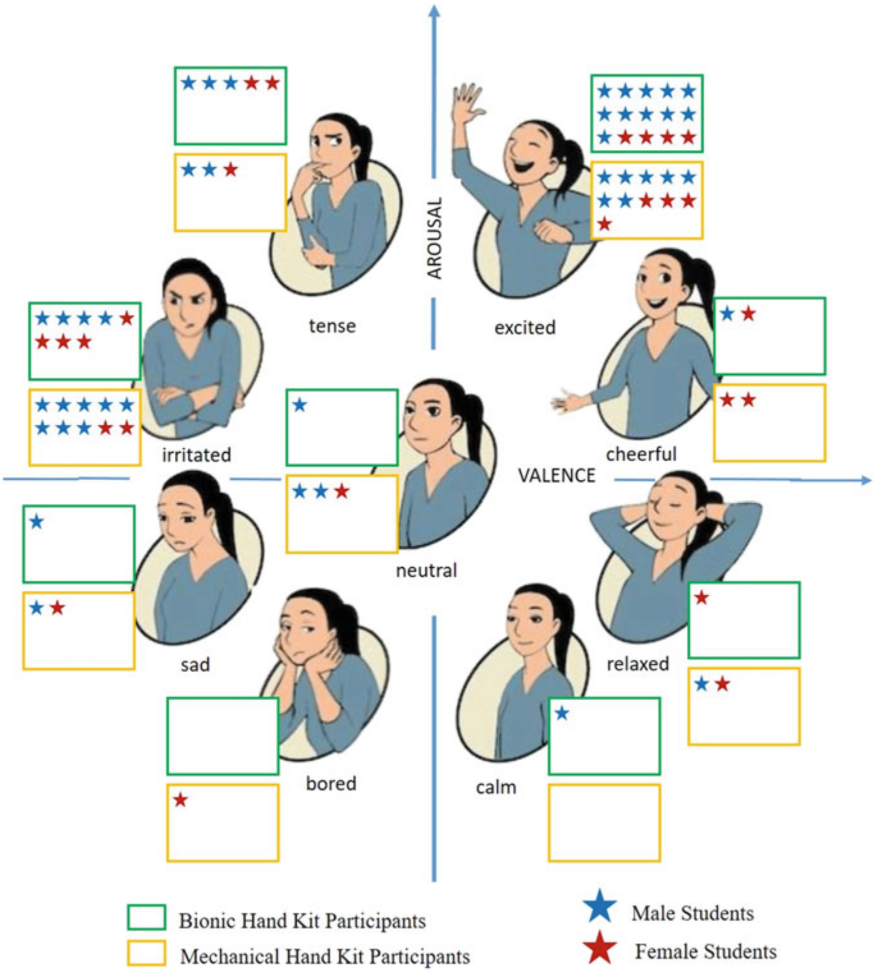

Fig. 2 Pictorial mood representation of participant students. Each star represents one student

5 Conclusion

This study was conducted with 68 students of 10–12 years of age from four schools in Delhi-NCR. It was found that the design and components of DIY STEM education kits hugely influence learners' experiences and attitudes. Students feeling excited and cheerful completed the kit assemblies faster as compared to those who faced difficulties and felt irritated and tensed. Students reported mild hand injuries also while assembling the kits. This shows the need for ergonomic intervention in kit design for usability and safety for creating quality experiences (Canina et al. 2020). Designers need to create STEM education products to include the average performers and students at risk (Bridgeland et al. 2008).

The study confirmed that students' experience and engagement quality regulates the assembly time, overall mood and after activity attitudes. Designers need to incorporate intuitiveness and the right affordances to reduce the kit assembly time and efforts. Further, kit parts need to be designed according to children's anthropometry and capabilities.

More studies are needed (Giannakos et al. 2017b, 2015) to better understand students' experiences and factors influencing them in DIY STEM education kit assembly activities. Consideration of ergonomic factors in designing DIY STEM education kits can add playfulness and encourage learners during assembly. Designers and parents may refer to the present study to device methodologies and instruments for considering and assessing ergonomic interventions in designing and choosing the right DIY STEM education kits and learning experiences in the future.

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Chapter 21
Ergonomics in Household Accidents

Reema Chaurasia and Maneesha Shukul

1 Introduction

The word ‘Home’ is a synonym of safety, comfort and warmth. A most spoken phrase ‘Home-sweet Home’ describes this as a privileged space as it is organized, arranged and decorated for leisure, comfort and satisfaction of its members.

Though, it is difficult to imagine a home as a dangerous entity but Shah (1987) describes this as a safe as well as a very dangerous place. Many studies have reported that number of accidents take place in this safe entity every year. As per Phelan et al. (2005) domestic accident is the leading cause of death and is a major reason for hospital admission and long-term disability.

Grandjean (1978) also stated that in developed countries accidents take the third place after defects of heart circulation and cancer.

Household Accidents

A house is a physical setting for family living. Maintenance and fulfilment of the various needs recognize and emphasize the need of establishing a very strong, healthy and good relationship among work, worker and workplace. But this is also an insisting fact that most of the time the importance of designing the home space is overlooked and many a times the needs of the inhabitant are not taken care that eventually result in a casualty.

According to Ganapathy (1985), ‘An accident is an event that takes place without foresight or expectation and results in some type of personal and/ or damage to equipment or property’ . In the words of Aydin (2016), accidents are unplanned, unexpected, preventable events that suddenly occur and may result in injuries and

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damages. Rumhi et al. (2020) defined home accidents for their study as ‘Any event occurring inside the home or in the immediate vicinity of the home that resulted in injury’. They called them unintentional home accident.

Generally, the accidents are known only after they have occurred and their causes are traced later but a home is a known surrounding where all the arrangements and placements of the household items, tools and supplies are known to the inmates therefore occurrence of an accident is alarming.

Determinants of Household Accidents

In developing countries, household accidents are one of the five leading causes of death (Goldman 1995). In developing and industrialized countries 10–30% of all hospital admissions are due to accidental injuries (Netra et al. 2017). According to Edlin and Golanty (2014), accidents in the home take a special toll on both young and elderly persons. They included falls, poisoning, fires, suffocation and drowning as the main categories of home accidents. They further emphasize that long cords dangling from appliances, draperies, or blinds should be placed well out of the way of a curious infant or toddler. Many a times deaths and injuries in fires result by inhaling smoke and toxic gases that reach victims before the flames do. ‘Improper storage or careless placement of a product plays a major role in home accidents’ as per Consumer Product Safety Education Program, U.S. (Shah 1987).

Joshi (1983) said that accidents just do not happen but are caused this means that accidents are not accidental but logical in the sense that they follow from foreseeable causes which could have been foreseen with intelligence and care and, therefore, could have been avoided.

Menon (1990) classified the causes of accidents as inadequate knowledge, improper attitudes and habits, unsafe behaviour, insufficient skills, environmental hazards. Florio (1962) has given the other possible causes of accidents as lack of knowledge, failure to assume personal responsibility, inadequacy of attitude, skill and knowledge. The causes of accidents by Stressor (1967) are unsafe behaviour and unsafe environment.

A community-based cross-sectional study (Bhanderi and Choudhary 2008) conducted in Petlad town in Anand district, Gujrat between September 2005 to December 2005 on 4086 individuals residing in a semi-urban area reported that there was total 69 domestic accidents occurred that made the incidence 1.7%. Devroey and Casteren (2006) recorded prevalence of 2.7% of accidents in Belgium in a study. Manjeeta et al. (2019) found that prevalence of domestic accidents was 8.25% with falls being the most common.

Ramifications of Accidents

Household accidents have a great deal of implications not only on the family of the victim but also on the country as well. The outcomes of such accidents can vary from small injury to the permanent disability or death of a family member. Many a times, the victim survives accident with physical or mental impairment that obstructs their activities for long term. These accidents, sometimes, have a social and/or economic impact too. The effects of accidents can be long-lasting in terms of treatment of injuries caused by accidents, sometimes, involve a large financial loss in health care. They can even snatch a bread-earner from a family and consequently this might influence the rest of the family member's other aspects of life including standard of living and family's quality of life too. The most commonly reported accidental injuries include head injury, open wounds, and poisoning.

Netra et al. (2017) carried out a community-based cross-sectional study between September 2016 to November 2016 on domestic accidents in the urban-field practices. They inferred that majority of the people who sustained injuries recovered completely (85.6%), while 12.5% had temporary disability and 1.9% had permanent disability.

Ergonomics and Household Accidents

The physical environment of the home is characterized by a confined physical space which is devoted to the use of an individual or set of household dwellers. These crossroad of individuals, tasks and environments pose an interesting challenge on interior designers and homemakers to revaluate the way they conceive the design for houses and arrange it, respectively. The home should be carefully designed keeping in mind the number, composition, type and need of the family. A home consists of several risk factors which are affected by the number of family members with respect to area, composition of the family specially if it composed of elderly and children. The layout of the different parts of the house, placement of the rooms and bathroom, design and material of all the household supplies, tools and equipment should not pose any safety threat on its dwellers.

The need for ergonomics grows when the need for safety arises. The data shows that the consequences of these accidents can be life-threatening. The familiar objects of house seem to be deceptively dangerous irrespective of age and gender. Consequently, the house is the ideal place where the discipline of ergonomics helps in maximizing safety and comfort and helps in improving and customizing living environment of its dwellers. The introduction of the new function, lifestyles and technologies have multiplied the threats in one's safest zone too.

Rationale of the Study

The arrangement, storage and placement of the household items require careful planning and a well-thought process. Many houses have objects lying scattered on the floor hindering movement. The stoppers and grab bars are, sometimes, missing from the doors and bathrooms, respectively, which result in serious mishappenings. The necessity of doing various jobs in the shortest possible time may often conflict with accident prevention duties and safety rules.

The field of Resource Management helps one to understand and apply the ergonomic principles of design and factors that should be considered while selecting, arranging, storing and placing various items in a house to overcome all the challenges and threats posed on inmates regarding their safety. This gives rise to the need to impart safety education to save the family from the loss of loved ones or the loss of an invaluable life of a family member due to household accidents.

There are various studies conducted on the different types of accidents in India and abroad, on the causes of accidents based on age and sex. But very few studies indicate association of the reasons of the accidents to the arrangement, placement and storage of household items. Hence, a study was planned to be conducted on the following objectives.

Objectives:

(1) To study the causes of household accidents with reference to ergonomic aspects.
(2) To study the level of knowledge and practices followed by homemakers regarding arrangement, storage and placement of household items in selected areas of the house to avoid accidents in home.

2 Methodology

A descriptive survey design was chosen to conduct the present study. With the help of a list obtained from Delhi Municipal Corporation, five slums were purposively selected from different zones. A sample of 18 households which had cases of accidents in past five years was selected through snowball sampling technique from each slum making a total of 90 homemakers as sample. Interview schedule was selected as tool to collect data considering anticipated low educational level of the sample. The schedule was prepared in Hindi as well as in English.

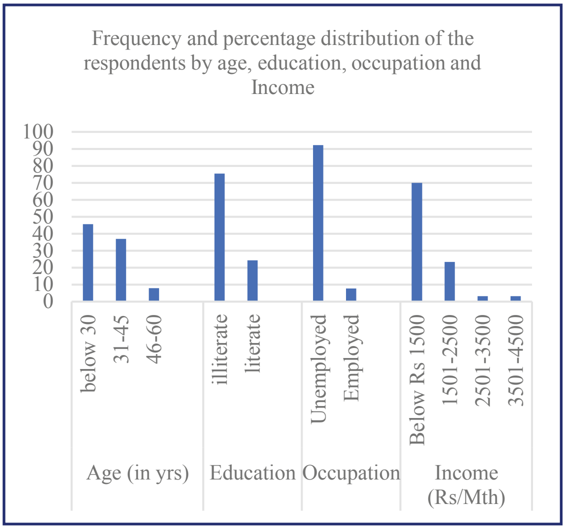
Summated rating scales were prepared to assess knowledge and practices regarding household safety in selected areas of the house. Knowledge scale had response structure of 'Yes' and 'No' which were ascribed scores of 2 and 1, respectively. Higher the score, better was the knowledge. The total possible scores were divided into 3 categories on the basis of equal interval to assess the level of knowledge. Practice scale had response structure of 'Always', 'Sometimes' and 'Never' which were ascribed scores of 3, 2 and 1, respectively. Higher the score better were the practices. The total possible scores were divided into three categories on the basis of equal interval to assess the practices.

After pre-testing, on the basis of the responses of the homemakers, reliability of the knowledge and practice scale were established through split-half method. The correlation values for knowledge scale was $r = 0.75$ and for practice scale it was $r = 0.65$.

Data collected were coded and tabulated. Descriptive as well as relational statistics was employed. Mean, standard deviation and percentage were applied to describe most of the information. Coefficient of correlation was computed to test the hypothesis.

3 Results of the Study

Background Information: The results of the study showed that less than half of the respondents were below 30 years of age. About 37% were between 31 to 45 years of age. Three-fourth of them were illiterate and 92% were unemployed. About 70% respondents' monthly income was below Rs. 1500. All the families had unauthorized possession and about two-third families had semi-pucca houses.



Occurrences of Accidents: The accidents in home occur due to several reasons such as falls, burns, scalds, wounds, cuts and scratches, electric shock. The information regarding occurrences of accidents was found in terms of frequency of occurrences who was the victim of accidents.

Falls: Fall is one of the cause of accidents. Out of the total sample, 47 cases reported accidents due to falls. Inability of clear vision is an indicator of physical health. Approximately 15% of the respondents met with the accidents due to this reason.

This was followed by using improper stool to reach a height, wet greasy flooring and improper illumination (Table 1). The cause 'Falling out of prem, cot and other furniture' was accountable for the least falls.

Burns: Accidents due to burning was considered as that caused by dry heat such as touching of hot vessel, catching the fire and so on. Out of the total sample, 34 cases were reported to be the victim of burns.

It was found that most (17.6%) of the accidents of burning occurred due to catching fire by clothes. 'Spilling up of kerosene' and 'sticking any part of the body to the hot vessel' was the second highest reason of burning accidents (Table 2). The

Table 1 Distribution of cases by the causes of falls

S. No.	Causes of falls	Total	
		f	%
1	Off tables, chairs and other furniture	4	08.5
2	Out of prem, cot and other furniture	2	04.3
3	By slipping on wet, greasy floor	4	08.5
4	By tripping on wet, greasy floor	5	10.6
5	Inability of clear vision	7	14.9
6	Improper illumination	5	10.6
7	Unavailability of light	3	06.4
8	Improper floor	5	10.6
9	The passageways from the sides of the bed to the doors obstructed with chairs, open dresser drawers, clothes or scatter rugs	3	06.4
10	Light switches inaccessible from the bed or the floor	3	06.4
11	Falling from the height while standing on chair or stool	6	12.8
	Total	47	100

Table 2 Distribution of cases by the causes of burns

S. No.	Causes of burns	Total	
		f	%
1	By falling right on the fire	3	08.8
2	fire by clothes	6	17.4
3	By turning stoves on	3	08.8
4	Fire caused by candles and light lamp	2	05.9
5	Cigarettes or 'bidis'	1	02.9
6	From crackers	4	11.8
7	Spilling up of kerosene	5	14.7
8	Improper disposal of burning matches	2	05.9
9	Sticking any part of the body to the hot vessel	5	14.7
10	Bursting of pressure cooker/explosion of the stove, etc.	3	08.8
	Total	34	100.0

reasons behind occurring these accidents were improper placements of supplies and equipment. Cigarette or 'bidis' accounted for least number of accidents.

Wounds, Cuts and Scratches: Wound is a cut on skin which becomes an outlet for blood and a gateway to disease producing microbes, whereas a cut is an accident when anything is being pierced, a long cut is made or anything pass with a sharp

Table 3 Distribution of cases by the causes of wounds, cuts and scratches

S. No.	Causes of wounds, cuts and scratches	Total	
		f	%
1	By tins	2	5.9
2	By broken things like glass etc.	5	14.7
3	By sewing items/instruments (sharper pointed)	2	05.9
4	Sharp or pointed tools or blade	9	26.5
5	Sticking out nails in boxes or board	5	14.7
6	By cutting or mixing tools	2	05.9
7	During closing or opening the doors	1	02.9
8	Objects from the highly placed cupboards	4	11.8
9	By sharp corner or edges of vessels during searching	1	02.9
10	Sharp corners of walls, doors, etc.	3	08.8
	Total	34	100.0

edge in the skin. Scratch can be defined as anything to tear or mark the surface of with something sharp or rough. In the present investigation these three were clubbed together and the relevant information was collected.

The results of the study under this section showed the need for compliance with the rules of ergonomics in the daily life. Approximately 26% of the respondents had wounds, cut and scratches while using or taking out sharp or pointed tools or blades.

Such injuries can be minimized if the principles of storage are followed and the proper space is provided to keep, unstack and stack the items of storage. It was found (Table 3) that nails sticking out from the board or boxes and broken things lying around in the house were marked as the second most caused (14.7%) reason behind these accidents whereas vessels and closing or opening of the doors were marked as the least (2.9%) caused reason for this kind of accidents. These accidents necessitate the inculcation of knowledge and creating awareness among the house dwellers.

Electrical Shock: Electric shock is the situation of passing the electricity from the body that may lead to the death. There was total 26 cases who experienced electric shock (Table 4). Shock was experienced by 23% people while they put finger in bulb holder but only 7% got shock while they unconsciously touched the electrical appliance and the same number of people got shock when they operated electrical switches.

Poisoning: It occurred in one case (male) due to drinking of household cleaner by mistake. He was in the age group of 41–50 years. As a result of this he was hospitalized and was so badly affected that he was terminated from his services.

Level of Knowledge of Homemakers regarding Arrangement, Storage and Placement of Household Items to Avoid Accidents in Selected Areas of the House:

Table 4 Distribution of cases by the causes of electrical shock

S. No.	Causes of electrical shock	Total	
		f	%
1	Open power points	5	19.2
2	Touching switches with wet hands	4	15.4
4	Repairing without switching it off	3	11.5
5	Overloading the plug point	4	15.4
6	Putting finger in bulb holder	6	23.1
7	Unconsciously touching the electrical appliance	2	07.7
8	Operating defective switches	2	07.7
	Total	26	100.0

To assess the knowledge and practices of the homemakers a rating scale was formulated comprising of the statements regarding safety in cooking area and safety in storage area.

It was found that 70% of the respondents had average knowledge about household safety. More per cent of respondents had good knowledge than those who had poor knowledge (Table 5). It was observed that approximately half of the respondents had average knowledge and more than one-fourth respondents had good knowledge about safety in cooking area. About three-fourth of the respondents had average knowledge about safety in storage area whereas only 15% of them had good knowledge about safety in storage area.

Practices of Homemakers regarding Arrangement, Storage and Placement of Household Items to Avoid Accidents in Selected Areas of the House:

It was observed that two-third of the respondents had average safety practices and about 17% had poor practices and nearly same percentage of the respondents had good practices regarding household safety (Table 6). Majority of the respondents had average safety practices in the cooking area and the similar percentage of respondents had average safety practices in storage area.

Coefficients of correlation was computed to test the hypothesis and no significant relationship was found between knowledge and practices of the respondents ($r = 0.0338$, N.S.) so the null hypothesis was accepted. Hence, this can be concluded that there was no relation between the knowledge and practices of homemakers regarding household safety.

Table 5 Frequency and percentage distribution of respondents by selected aspects of knowledge scale

Level of knowledge on selected aspects	Respondents	
	f	%
Knowledge of safety in cooking area		
Poor knowledge (12–15)	18	20.0
Average knowledge (16–20)	48	53.3
Good knowledge (21–24)	24	26.7
Mean: 18.00		
S.D.: 1.76		
Total	90	100.0
Knowledge of safety in storage area		
Poor knowledge (15–20)	12	13.3
Average knowledge (21–25)	63	70.0
Good knowledge (26–30)	15	16.7
Mean: 22.51		
S.D.: 1.93		
Total	90	100.0
Level of knowledge for total scale		
Poor knowledge (27–36)	15	16.7
Average knowledge (37–44)	55	61.11
Good knowledge (45–54)	20	22.22
Total	90	100.0
Mean: 40.51		
S.D.: 3.69		

4 Discussion

The present study revealed that 'falls' were amongst the most caused accidents. Approximately 15% of the respondents met with this kind of accident. A cross-sectional study conducted in Puducherry by Rehman et al. (2020) reported that amongst 59 families 42% had adult victims, 37% were due to falls, 45% had upper limb injuries and 43% occurred in kitchen. In another study conducted in Oman (Rumhi et al. 2020) showed that the most prevalent causes for home accidents were 'falls' in 53.7% children, followed by 'struck by/against-animate/inanimate mechanical force' in 15.1% children. 'Poisoning' was the third major cause in 8.8% children whereas poisoning was reported by only one respondent in the present study.

Debnath et al. (2014) assessed the knowledge of the rural mothers with respect to common domestic childhood injuries and home safety measures. Almost 96% of the respondents had moderate knowledge, while 3.9% of the respondents had inadequate level of knowledge regarding home safety. They further reported that 98.3% of the

Table 6 Frequency and percentage distribution of respondents by the different aspects of safety practices

Safety practices on selected aspects	Respondents	
	f	%
Safety practices in cooking area		
Poor practices (10–16)	17	18.9
Average practices (17–23)	58	64.4
Good practices (24–30)	15	16.7
Total	90	100.0
Mean: 18.50		
S.D.: 2.13		
Safety practices in storage area		
Poor practices (18–29)	16	17.8
Average practices (30–40)	57	63.3
Good practices (43–54)	17	18.9
Total	90	100.0
Mean: 34.30		
S.D.: 3.51		
Overall safety practices		
Poor practices (28–46)	17	18.89
Average practices (47–65)	57	63.33
Good practices (66–84)	16	17.78
Total	90	100.0
Mean: 52.80		
S.D.: 5.64		

respondents had moderate level of practice. While the present investigation conducted that most of the respondents had average knowledge and approximately one-fifth of the respondents had good knowledge of the safety practices.

5 Conclusion

The provision of the facilities in a house is for the comfort of its inmates. Equipment and tools facilitate and increase the amount of ease to carry out the tasks, however their arrangement, placement and storage needs to be so planned that they do not cause any accidents. Falling from the stool, inability of clear vision, wearing improper clothing that catches fire easily while cooking, improper storage of sharp and pointed tools, placement of electrical points at improper places were found to be the most mentioned reasons for the occurrences of accidents as per the findings of the study. The average knowledge and safety practices of the homemakers also indicated that they were not very cautious in placement and storage of the household items. The results of the study signified that there is a dire need to improve safety practices and to enhance the knowledge of the homemakers and other family members about the safety regulations to save the invaluable loss of money, time and loved ones.

Relevance and Scope:

Resource Management experts, architects and interior designers should put forth their efforts to apply the principles of ergonomics so as to establish a good relationship among all the components of the house to ensure safety of all the inmates. Therefore, the findings of the study will be very meaningful for the designers, architects, ergonomists and safety engineers to create a safe house.

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Chapter 22
Evaluation of Directional Control-Response Stereotype Among the Population of Eastern Zone of India

Piyali Sengupta, Monalisha Banerjee, and Prakash C. Dhara

1 Introduction

In our day-to-day lifestyle, displays and controls perform an important part. Nowadays displays and controls are everywhere surrounding us. Say for example, in our household works, in our way of traveling, in our work stations, office, shopping malls, doctor's clinics, schools, colleges, cafeteria and in all other many more public places. Displays and controls provide the means of communication between people and machines in human–machine systems. We can operate a machine through a control and can get the information about the operational status of the control we have performed. Control devices enable operators to take necessary actions and change the states of a human–machine system (Kang and Seong 2001).

The interaction of people with equipment and machinery is mainly achieved through a two-way exchange of information via displays and controls, demanding information processing and decision-making skills. When people operate a control they have expectations about what it will do and what effect it will have on a display. The relationship between a control movement and the effect most expected by a population is known as a population stereotype or direction-of-motion stereotype and such a relationship is said to be compatible.

The main idea of incorporating population stereotypes into design is that a given movement of a control should result in the most expected movement of the corresponding display (Courtney 1994). Control-display configurations designed with established population stereotypes taken into consideration have been found to be advantageous in that they yield higher performance, more consistent performance, and increased resistance to stress and fatigue. One of the goals of researchers in human factors is to explore the common perceptual and motor skills in daily life operations, directions-of-motion, and descriptions of movement. It was reported long ago that

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human beings are consistent in their choice in selecting one response to a stimulus among a set of alternatives. The term “population stereotype” is used to describe this response preference, which refers to long-term habits and well-ingrained knowledge of a particular population (Chan et al. 2003). These type of studies are lacking in Indian population. However, for designing purposes of controls and displays, there is a need to establish population stereotype data. In the present study, an attempt was taken to evaluate the directional control response stereotype among the Eastern Indian population. Apart from that the influence of gender, different states (regions) and educational status on directional control response stereotype were also assessed.

2 Methodology

2.1 Selection of Site

The study has been conducted in different areas of Eastern zone of India. From West Bengal (WB) state different districts and some villages under subdivisions were selected at random such as, Paschim and Purba Medinipur, Howrah, Bankura, Bishnupur, South 24 Pargana, North 24 Pargana, etc. From Orissa (OR) state different areas like Balasore, Chandipur, Bhubneswar were selected, from Jharkhand (JR) state different areas of Jamshedpur, Ghatsila were selected, from Bihar (BR) state Darbhanga, Sitamarhi, Lohapatty, Sitakund, Mohanpur and so many other areas were selected for the study.

2.2 Selection of Subject

The study was conducted on about 4885 subjects having the age range 18–60 years were selected from random sampling method. The subjects were further classified according to gender, educational status and states.

2.3 Ethical Consideration

All the subjects were volunteered for the study and written consent was taken from the subjects. The study protocol was explained to the Human Ethical Committee of the institution (Vidyasagar University) and approved thereafter. The experiments were performed in accordance with the ethical standards of the Helsinki Declaration.

2.4 Inclusion and Exclusion Criteria

Subjects having the age range of the study (mentioned above), physically fit and have no cognitive impairment were included in the study. Subjects having any acute illness, undergone recent surgery, had visual, hearing or cognitive impairment, physical handicap interfering with the evaluation were excluded from the study.

2.5 Study of Control-Response Stereotype

To study the control-response stereotype different prototype models were prepared for different stereotype protocols. In this regard, the different control and display systems were developed to record the motion stereotype of the subjects. However in the present study, three types of stereotype models were prepared each of which had an analog display (Fig. 1). Those three types of stereotype models are- a rotary control knob and a display system in which an indicator moves in horizontal direction (HD) (Fig. 1a, b), a rotary control knob and a display system in which an indicator moves in vertical direction (VD) (Fig. 1c, d), a control knob and a display system in which an indicator moves in semi-circular direction (CD) (Fig. 1e, f). The subjects were asked to operate the control knob to cause a movement of the indicator in a particular direction, i.e. Move to Left (ML), Move to Right (MR), Move to Up (MU) and Move to down (MD). The effort of the subject to rotate the control knob in either clockwise (CW) or in anti-clockwise (ACW) direction for the desired movement of display indicator was recorded.

2.6 Study of Educational status

The educational status of the subject was assessed by questionnaire method. The subjects were categorized according to the level of education as mentioned below:

(a) Illiterate (b) primary (c) secondary (d) graduate (e) Post graduate.

Efforts were made to find out relationship between the education level and the motion stereotype of the subjects.

2.7 Statistical Analysis

Data were summarized into mean and standard deviation (SD) values by using Microsoft Excel (Office 2010). Frequencies and percentages were used for categorical variables to summarize data. The difference of proportions in groups was assessed by the Chi-square test for categorical variables.

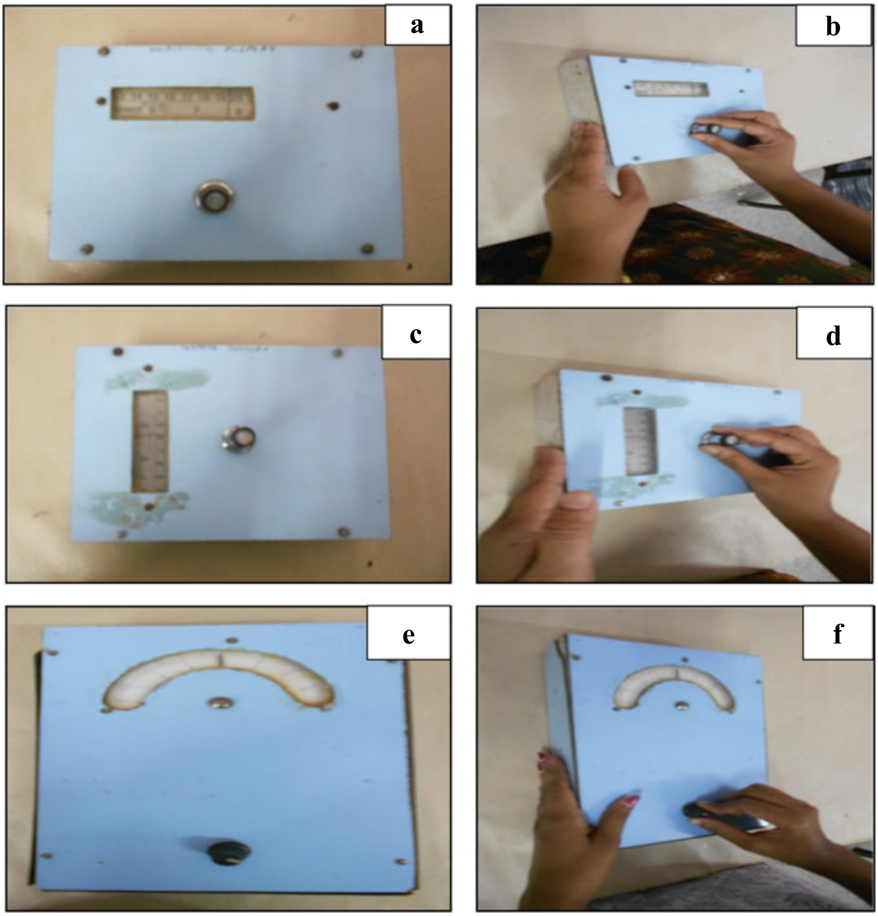

Fig. 1 Operation of stereotype model with analog display **a** front view of the horizontal display with rotary switch, **b** operation of the horizontal display protocol, **c** front view of the vertical display with rotary switch, **d** operation of the vertical display protocol, **e** front view of the semi-circular display with rotary switch, **f** operation of the semi-circular display protocol

3 Results

Table 1 shows the distribution of subjects in different groups. It was observed from the table that within the studied locations, total 4885 number of subjects were included in the study. Among them 2447 (50.1%) were male and 2438 (49.9%) were female. 43.1% subjects were taken from West Bengal state, 18.9% from Bihar state, 19.2% from Jharkhand state and 18.8% from Orissa state. Almost same percentage of respondents belonged to graduate category (25.4%) as well as illiterate category (25.3%). Very few percentage (8.47%) of the selected population represent the post graduate category. However, when gender-wise variation was considered it

Table 1 Distribution of subjects among different groups

Groups	Categories		f (%)	Total f (%)
Gender	Male		2447 (50.1)	4885
	Female		2438 (49.9)	
States	WB	Male	1042 (49.5)	2107 (43.1)
		Female	1065 (50.5)	
	BR	Male	481 (52.2)	922 (18.9)
		Female	441 (47.8)	
	JR	Male	453 (48.4)	936 (19.2)
		Female	483 (51.6)	
	OR	Male	471 (51.2)	920 (18.8)
		Female	449 (48.8)	
Educational status	Illiterate	Male	450 (18.4)	1234 (25.3)
		Female	784 (32.2)	
	Primary	Male	534 (21.8)	847 (17.3)
		Female	313 (12.8)	
	Secondary	Male	597 (24.4)	1151 (23.6)
		Female	554 (22.7)	
	Graduate	Male	657 (26.8)	1239 (25.4)
		Female	582 (23.9)	
	Post graduate	Male	209 (8.54)	414 (8.47)
		Female	205 (8.41)	

was observed that the percentage (32.2%) of illiteracy was higher in female subjects than in males (18.4%). The results also show that from primary to post graduate categories, educational status was lower in percentage for both sexes.

The control response stereotype was determined for the population of Eastern India with rotary control and analog display. As stated in the methodology part in this concern three prototypes were prepared. The results (Table 2) of the study revealed that a relatively larger percentage (77.1%, 80.6% and 79.5%, respectively)

Table 2 Responses of the subjects while operating three prototype models of control response stereotype among all the selected subjects (n = 4885) of Eastern India

Stereotype model	Direction of movement	CW f (%)	ACW f (%)
HD	MR	3766 (77.1)	1119 (22.9)
	ML	1119 (22.9)	3766 (77.1)
VD	MU	3884 (79.5)	1001 (20.5)
	MD	1001 (20.5)	3884 (79.5)
CD	MR	3937 (80.6)	948 (19.4)
	ML	948 (19.4)	3937 (80.6)

Table 3 Comparison of respondents while operating the control response stereotype models between male and female subjects of Eastern India (Male = 2447, Female = 2438)

Stereotype model	Direction of movement	Actions				χ^2
		CW (%)		ACW (%)		
		Male	Female	Male	Female	
HD	MR	83.0	71.2	17.0	28.8	96.25**
	ML	17.0	28.8	83.0	71.2	–
VD	MU	77.1	81.9	23.0	18.3	16.89**
	MD	23.0	18.3	77.1	81.9	–
CD	MR	78.9	82.2	21.1	17.8	8.62*
	ML	21.1	17.8	78.9	82.2	–

** $p < 0.001$* $p < 0.05$

of the subjects moved the rotary control in clockwise direction for the rightward movement of analog pointer in horizontal and circular displays and for the upward movement of the pointer in case of vertical display.

Control response stereotype responses were recorded and variation was noted between male and female subjects. Table 3 shows that there was a significant difference ($p < 0.001$, $p < 0.05$) of responses between male and female subjects. For horizontal direction (move to right), clockwise movement was higher in males than in females (83% and 71.2%, respectively) but anti-clockwise movement was significantly ($p < 0.001$) higher in females than in males (28.8% and 17%, respectively). However for both the vertical (move to up) and semi-circular (move to right) direction clockwise movement was significantly ($p < 0.001$, $p < 0.05$) higher in females (81.9% and 82.2%, respectively, for vertical and semi-circular display, respectively) and anti-clockwise movement was higher in males (23% and 21.1% for vertical and semi-circular display, respectively).

State-wise comparison of the respondents while operating stereotype models was done (Table 4). In this regard to shorten the table only clockwise actions were granted for right side and upward movements of the stereotype models. The results depicted that significant differences ($p < 0.001$) of respondents were observed for different states while using different stereotype models. The differences were noted for both the subjects and for all the subjects. In case of males, a highest percentage of subjects from Bihar (90.1%) state operated the HD model in clockwise direction for moving the pointer right side followed by Jharkhand (89%), Orissa (85.7%) and West Bengal (67.3%) states. When operating the VD model highest percentage of subjects from Jharkhand (88.7%) state responds to clockwise action for upward movement followed by Bihar (80%), West Bengal (74.9%) and Orissa state (64.9%). While operating the CD model highest percentage of subjects from Bihar (92.2%) state responds to clockwise action for right side movement followed by Jharkhand (86.8%), Orissa (75.2%) and West Bengal (61.4%). In case of female subjects, a highest percentage of subjects from Bihar (82.6%) state operated the HD model in clockwise direction for moving the pointer right side followed by West Bengal (71.1%), Jharkhand (69.3%), Orissa

Table 4 State-wise comparison of respondents while operating the control response stereotype models.

Subjects	Stereotype model	Direction of movement	Actions	States				χ^2
				WB	BR	JR	OR	
Male WB = 1042 BR = 481 JR = 453 OR = 471	HD	MR	CW	67.3	90.1	89.0	85.7	129.50**
			ACW	32.7	9.95	11.1	14.4	–
	VD	MU	CW	74.9	80.0	88.7	64.9	288.80**
			ACW	25.2	20.1	11.3	35.1	–
	CD	MR	CW	61.4	92.2	86.8	75.2	105.65**
			ACW	38.7	7.86	13.2	24.8	–
Female WB = 1065 BR = 441 JR = 483 OR = 449	HD	MR	CW	71.1	82.6	69.3	61.8	331.62**
			ACW	28.9	17.4	30.8	38.2	–
	VD	MU	CW	78.0	76.5	94.0	79.0	321.98**
			ACW	22.1	23.5	6.41	21.1	–
	CD	MR	CW	71.9	83.3	92.2	81.5	223.54**
			ACW	28.2	16.7	7.79	18.6	–
All subjects WB = 2107 BR = 922 JR = 936 OR = 920	HD	MR	CW	69.2	86.4	79.2	73.8	429.59**
			ACW	30.8	13.7	21.0	26.3	–
	VD	MU	CW	76.5	78.3	91.4	72.0	604.05**
			ACW	23.7	21.8	8.86	28.1	–
	CD	MR	CW	66.7	87.8	89.5	78.4	308.89**
			ACW	33.5	12.3	10.5	21.7	–

** $p < 0.001$

(61.8%) states. A highest percentage of subjects from Jharkhand (94%) state operated the VD model in clockwise direction for moving the pointer upward followed by Orissa (79%), West Bengal (78%) and Bihar (76.5%) states. When operating the CD model highest percentage of subjects from Jharkhand (92.2%) state responds to clockwise action for right side movement followed by Bihar (83.3%), Orissa (81.5%) and West Bengal (71.9%). However when considering all the selected subjects, it was noted that while operating HD model highest percentage of subjects from Bihar (86.4%) state responds to clockwise action for right side movement followed by Jharkhand (79.2%), Orissa (73.8%) and West Bengal (69.2%) state. While considering the VD model highest percentage of subjects from Jharkhand (91.4%) state responds to clockwise action for upward movement followed by Bihar (78.3%), West Bengal (76.5%) and Orissa (72%) states. When operating the CD model highest percentage of subjects from Jharkhand (89.5%) state responds to clockwise action for right side movement followed by Bihar (87.8%), Orissa (78.4%) and West Bengal (66.7%). So if we observe in a whole we can find that the results of the present study reported that for all the three stereotype models percentage respondents were highest from Bihar and Jharkhand states for clockwise actions while operating the knob right side and upward.

Effect of educational status on the control response stereotype was also assed in the present study. In this regard, the educational status of the subjects of Eastern India was evaluated and classified thereafter in different categories ranging from illiterate to post graduate.

The control movement stereotype was assessed according to the different category of the educational status (Table 5). In the present table only clockwise to increase for move to right, move to up and move to right concept were taken in consideration for all three stereotype models, respectively, to shorten the table. It was observed from the results that there was a significant ($p < 0.001$) categorical variation among different educational levels for both male and female subjects. The results of the study depicted that in case of male subjects for both HD (move to right) and VD (move to up) models (Figs. 2 and 3) the percentage reported clockwise action was highest in post graduate category (88.5% and 96.7%, respectively) followed by primary (86.7% and 85.8%, respectively) and illiterate (84.2% and 90.2%, respectively) category. In CD (move to right) model (Fig. 4) the percentage was highest in illiterate (83.8%) category followed by post graduate (80.4%) category. Whereas in case of female subjects for all the three stereotype models the highest percentage of subjects controls the knob to increase the value in clockwise action belongs almost to the illiterate category (86.5%, 84.9% and 84.3% for HD, VD and CD models, respectively). When we consider all the subjects it was noted that for all the three stereotype models, clockwise actions were more or less decreases from the illiterate category to post graduate category (Decreases from 85.4% to72.3%, 87.6% to 83.7% and 84.1% to 75.6% for HD, VD and CD models, respectively).

4 Discussion

The present study was conducted in Eastern zone of India. The directional control response stereotype was evaluated and the effect of gender, educational status and regional variation were assessed. It was found from the present study that the illiteracy was 25.3% in the selected population with a higher in percentage in females than in males. When considering all the selected subjects a relatively larger percentage moved the rotary knob in clockwise direction for the right side movement of the analog pointer in HD and CD models and upward movement of the pointer in VD model. So the present study hypothesized that a higher percentage of the selected population were habituated for controlling a rotary knob in clockwise direction to move the pointer upward and/or right side. The finding of the present study was in accordance with the study of Hotta and Yoshioka (1988).

In gender wise comparison of directional control response stereotype, it was found that clockwise action was higher in males than in females for HD model. However, for VD and CD models clockwise action was higher in females than in males. Previous studies reported that there are significant different patterns of brain activation between

Table 5 Variation of respondents (%) while operating different models of control response stereotype according to different categories of educational status among the subjects of Eastern India (n = 4885)

Gender	Educational status	Actions	HD		VD		CD	
			MR	ML	MU	MD	MR	ML
Male (N = 2447)	Illiterate (n = 450)	CW	84.2	18	90.2	12	83.8	18.4
		ACW	18	84.2	12	90.2	18.4	83.8
	Primary (n = 534)	CW	86.7	14.4	85.8	15.4	75.7	25.5
		ACW	14.4	86.7	15.4	85.8	25.5	75.7
	Secondary (n = 597)	CW	77.1	13.6	78.6	12.1	78.9	11.7
		ACW	13.6	77.1	12.1	78.6	11.7	78.9
	Graduate (n = 657)	CW	61.5	38.2	66.7	33.0	65.8	33.9
		ACW	38.2	61.5	33.0	66.7	33.9	65.8
	Post graduate (n = 209)	CW	88.5	31.6	96.7	23.4	80.4	39.7
		ACW	31.6	88.5	23.4	96.7	39.7	80.4
χ^2			137.95**	–	123.04**	–	151.21**	–
Female (N = 2438)	Illiterate (n = 784)	CW	86.5	26.8	84.9	15.2	84.3	16.2
		ACW	26.8	86.5	15.2	84.9	16.2	84.3
	Primary (n = 313)	CW	70.0	28.4	81.2	17.3	78.6	19.8
		ACW	28.4	70.0	17.3	81.2	19.8	78.6
	Secondary (n = 554)	CW	79.8	20.4	86.6	13.5	84.7	15.5
		ACW	20.4	79.8	13.5	86.6	15.5	84.7
	Graduate (n = 582)	CW	65.1	34.9	74.1	25.9	72.9	27.1
		ACW	34.9	65.1	25.9	74.1	27.1	72.9
	Post graduate (n = 205)	CW	56.1	43.9	70.7	29.3	70.7	29.3
		ACW	43.9	56.1	29.3	70.7	29.3	70.7
χ^2			247.75**	–	230.65**	–	226.14**	–
All subjects (N = 4885)	Illiterate (n = 1234)	CW	85.4	14.6	87.6	12.4	84.1	15.9
		ACW	14.6	85.4	12.4	87.6	15.9	84.1
	Primary (n = 847)	CW	78.4	21.6	83.5	16.5	77.2	22.8
		ACW	21.6	78.4	16.5	83.5	22.8	77.2
	Secondary (n = 1151)	CW	78.5	21.5	82.6	17.4	81.8	18.2
		ACW	21.5	78.5	17.4	82.6	18.2	81.8
	Graduate (n = 1239)	CW	63.3	36.7	70.4	29.6	69.4	30.6
		ACW	36.7	63.3	29.6	70.4	30.6	69.4
	Post graduate (n = 414)	CW	72.3	27.7	83.7	16.3	75.6	24.4
		ACW	27.7	72.3	16.3	83.7	24.4	75.6
χ^2			309.39**	–	299.52**	–	335.27**	–

** $p < 0.001$

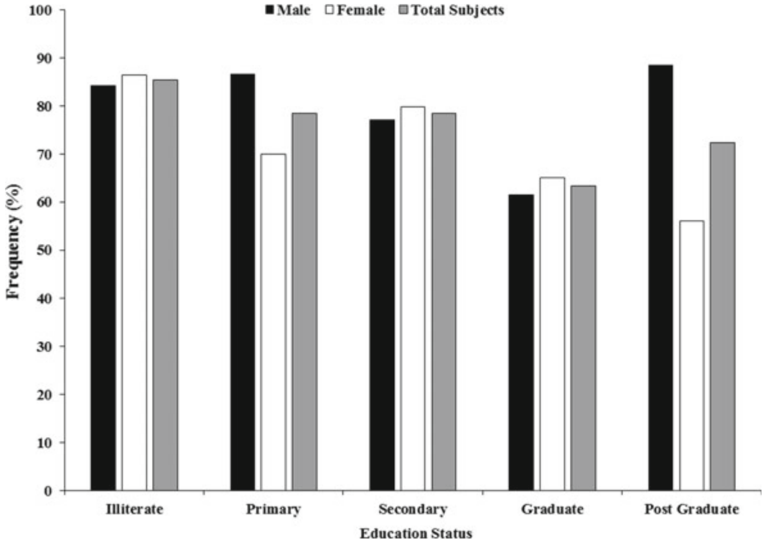

Fig. 2 Variation of respondents (%) (clock wise) while operating HD model of control response stereotype in move to right (MR) direction according to the different categories of educational status

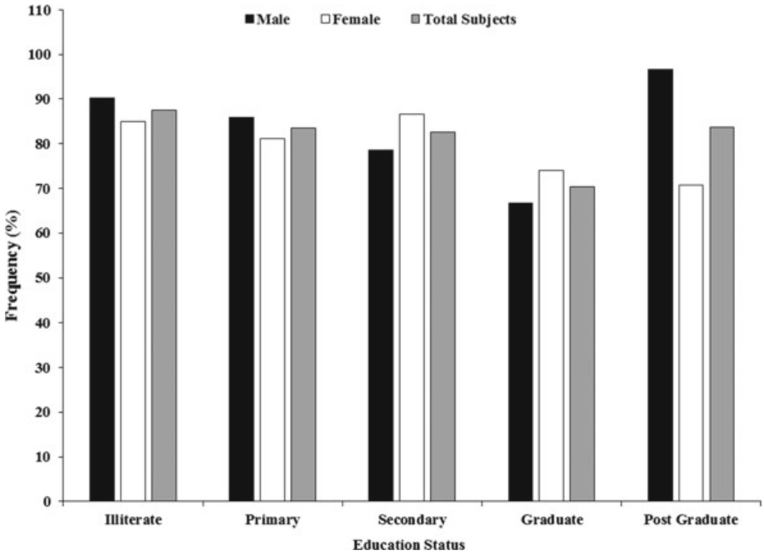

Fig. 3 Variation of respondents (%) (clock wise) while operating VD model of control response stereotype in move to up (MU) direction according to the different categories of educational status

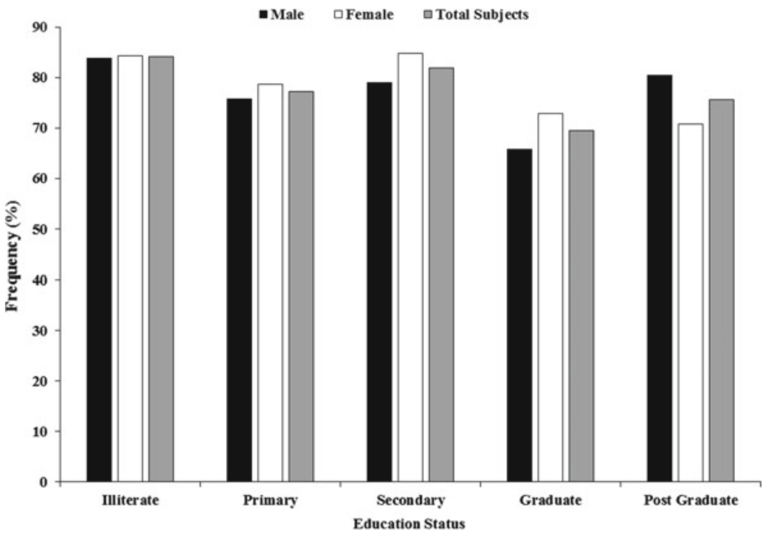

Fig. 4 Variation of respondents (%) (clock wise) while operating CD model of control response stereotype in move to right (MR) direction according to the different categories of educational status

male and female subjects in response to a variety of cognition-related tasks while using various models (Bell et al. 2006). Thereby the findings of the present study support the hypothesis that the cognitive function might also be influenced by gender difference. The literature says that the gonadal hormones might play a significant function in the development of sex differences in cognition (Gooren and Kruijver 2002; Thijssen 2002).

To find out the regional effect on population stereotype, state-wise comparison of the respondents was performed. While summarizing the results reported that for all the three stereotype models percentage respondents were highest in Bihar and Jharkhand states for clockwise actions while operating the circular knob towards right side and/or upward direction. These findings reflect that there might be some regional variations on population stereotype. The study of Rhoads (2004) reported that cultural differences in independence-inter dependence were evident in the field of basic cognitive processing tasks. So it can be speculated from the results of the study that the regional variations among the states might be due to the habituation, training for the regional stereotypical settings, etc. Previous studies also reported that cognition is the information-handling aspect of human behavior (Lezak 1995) like perception, memory, thinking, learning, expressive functions, attention and decision-making. Thereby it can be said that the stereotypical control of a person while operating a control-display unit independently depends on the decision-making process of that person. The findings of the present study are in agreement with the study of Chan and Chan (2007) who reported that the control movement stereotype may be population specific.

Apart from the regional variation attempts were also taken to find out the effect of educational status on the control response stereotype. In this regard, the educational status of the subjects of Eastern India was evaluated and classified thereafter in different categories ranging from illiterate to post graduate. Almost in both the sexes, the percentage of respondents for clockwise action for all the three models was higher in illiterate category of the educational status. It was found from the study of Falch and Sandgren (2011) that the cognitive ability is positively affected by the educational level. When we consider all the subjects it was noted that for all the three stereotype models, clockwise actions were more or less decreased from the illiterate category to post graduate category. The findings of the present study might reflect that because of the illiteracy of the subjects who chose clockwise action for right side and/or upward movement might be trained to handle that kind of models or they were habituated from their childhood to operate the models in such directions. However, the data on experience and habitats of the selected population are lacking in the study. Further study is required in this field. In the present study when the education would increase the percentage of subjects, responds for clockwise action were also decreased. Because they will think before they use the prototype model. A sharp increase was noted in the variation of respondents of graduate to post graduate participants while operating different models of control response stereotype according to different educational levels. It can be stated from the findings of the present study that the higher level of education might increase the decision making capability of a person. Previous literature also reported that the higher level of education is associated with a better performance on different tests of cognition (Cagney and Lauderdale 2002; Lee et al. 2003), including executive function (Wecker et al. 2005) and set shifting (van Hooren et al. 2007). So there might be some effect of educational status on population stereotype.

There is lack of researches on population stereotype. Especially it is lacking in Indian population. However, there is a need to standardize different directional control-response stereotype to improve the efficiency and overall system performance in man–machine system (Chan and Chan 2011). Rotary controls are commonly used with linear and circular displays. Determination motion stereotype of these controls is required for the design of control panels used in man–machine interfaces for improved human performance (Chan and Chan 2003). Chan et al. (2003) studied that the directional pointer and bottom scale side are preferable for all control positions for faster response. Chan and Chan (2007) suggested that the circular display is a better partner than the digital counter in working with rotary control for simple tasks of generally increasing and decreasing display values.

5 Conclusion

The findings of the present study concluded that a higher percentage of the selected population were habituated for controlling a rotary knob in clockwise direction to move the pointer upward and/or right side. There was an influence of gender on directional control response stereotype among the population of eastern India. The study also concluded that the directional control response stereotype is different in different regions of India. There was a state-wise variation of directional control response stereotype. It may be concluded from the study that the educational status had an emphasis on population stereotype. The directional control response stereotype data is lacking in India. There is a need to build data on population stereotype in Indian population for designing of controls and displays to improve productivity and occupational safety.

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Chapter 23
Experimental Study on the Effect of Container and Worker Characteristics on a Lifting Task

Saman Ahmad and Atif Saleem

1 Introduction

Despite widespread mechanization, manual material handling (MMH) is associated with nearly all types of industries. It remains indispensable in situations requiring instant decisions, depending on the situation (Maiti and Ray 2004). The cost of mechanization and availability of cheap labor may also contribute. It has been reported that approximately one-third of all industrial jobs in the US involve some form of MMH (Han et al. 2005). Further, the load handled by workers are often above their physical capability, thereby exposing them to the risk of low back pain (LBP) and musculoskeletal injuries (Afshari et al. 2017). MMH and lifting have been implicated in the development of work-related LBP (Arjmand et al. 2015; Pinder and Frost 1991), which causes not just human suffering but also results in considerable economic burden to the society. Four of every five injuries are related to back pain caused by MMH, with almost 50% back pains being related to lifting (Afshari et al. 2017).

A review of literature spanning 10 years (1997–2007), placed the estimated LBP cost between \$84.1 and \$624.8 billion (Dagenais et al. 2008). Liberty Mutual Research Institute for Safety reported that workplace overexertion injuries (predominantly caused by lifting, pushing, pulling and manual materials handling) accounted for about 24% of total workers' compensation costs. In the year 2000, nearly 63% of all non-fatal industrial injuries were musculoskeletal, resulting in 9 man-days lost per accident in India. 35% of these were the result of MMH-related accidents (ICMR Bulletin, 2000). Low back injuries constituted about 16% of all workers' compensation cases and 33% of the total cost (Dempsey 2002).

Many factors, both task and worker-related, have an effect on the risk of LBP and lifting task performance. While some of these factors have been accounted for in risk

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analysis standards, many are still relatively unexplored. It has been recommended that factors like gender, load, back muscle strength and back pain be taken into consideration for manual lifting tasks (Andersen et al. 2018). Significant effect of laboratory environment and box size on oxygen intake has been reported (Singh et al. 2012a). Job physical exposure, history of LBP, physical activities outside of work, and psychosocial factors have also been implicated for LBP in a manufacturing settings (Kapellusch et al. 2014).

It is generally accepted that the size and shape of container have an effect on back compressive forces (BCF) and MAWL in lifting tasks. Singh et al. showed that MAW is affected by box size (Singh et al. 2012b). MAWL tends to decrease with increase in container size (Lee 2005; Lee and Cheng 2011; Singh et al. 2012b). Larger boxes result in higher BCFs (Abadi et al. 2016). Use of smallest possible container width has been recommended (Lee and Cheng 2011). A smaller width results in a decreased compressive and shear forces on the vertebrae owing to the lower distance between the center of gravity of the load and L5/S1 disc. Interactive effects of container dimensions with various task parameters have also been documented. A relationship of box width with horizontal distance and starting height has been reported (Potvin and Bent 1997). For large boxes, MAWLs are significantly affected by frequency (Ciriello 2003), but not by the vertical distance of lift (Ciriello 2005). Presence of handles also has an affect on MAWL. Lifting loads with handles is safer and less stressful than loads without handles (Jung and Jung 2003). Proper handle position may reduce the musculoskeletal stress and in turn increase user satisfaction. It has been reported that while subjects preferred upper handles in many MMH cases, handle position was largely dependent on box size and stacking height (Jung and Hwa 2010). Body part discomfort ratings indicated that an upper handle was less stressful for a relatively small box as compared to a big one and mid to upper handles were less comfortable for a big box (Jung and Hwa 2010).

Load lifting task is dependent not just on the characteristics of lift but also on worker characteristics like age, gender, weight, etc. A significant effect of gender and age on lifting capacity has been reported (Matheson et al. 2014). Aerobic capacity in adults has been found to decline by about 10% for each decade of life (Crawford et al. 2010). MAWL of older female was found to be significantly lower than their younger counterparts (Chen et al. 2017). For male workers, MAW increased with age, reached a peak in the age group of 29–38 years and declined gradually thereafter (Girish et al. 2018). For similar lifting tasks, older workers tended to have higher oxygen uptake and heart rate than their younger counterparts (Singh et al. 2012c). However, some researchers have reported contradictory findings. According to Anderson et al., there was no association between age and physical exertion of blue-collar workers (Andersen et al. 2018). Age-related physiological changes have been implicated for the increased LBP risk in older workers (Song and Qu 2014a, b). No significant age-related differences were found between physically active older population and younger groups (Hamid and Tamrin 2016). Gall and Parkhouse found very little difference between physical capacity of younger and older workers. In fact, they opined that workers may maintain task-specific physical capacity as age progresses

(Gall and Parkhouse 2004). Further, experienced workers have been found to lift more weight compared to inexperienced one (Maiti and Ray 2004).

One of the most commonly used tools for assessing the risk of LBP is the revised NIOSH lifting equation (RNLE). For the development of RNLE, three distinct criteria viz. physiological, psychophysical and biomechanical were considered. The same parameters were used in the evaluation of lifting task in the present study. Hence, the present study aims to establish the effect of container (dimensions and handle position) and worker characteristics (age and experience) on MAWL, oxygen uptake and BCF (at L5/S1) of a worker performing a lifting task.

2 Methodology

In order to investigate the effect of the various parameters identified, experimental investigations were carried out in the Department of Mechanical Engineering, Z.H.C.E.T. The entire study was divided into two parts. A 2 × 3 full factorial designs for both the studies were used.

Independent variables for study-1 were box size and handle position. Two levels of handle positions, i.e. at a distance 1/3 and 1/2 of the height from the top (position 1 and 2, respectively) were chosen for investigation. Steel handles, 15 cm wide were used. Three box sizes (shown in Table 1) were chosen. All boxes were made of wood and had a false bottom. The length and depth of the boxes were varied while keeping the volume constant.

The box configuration that resulted in maximum MAWL was chosen for the second set of experiments. Three age group (20–25, 30–35 and 40–45 years) and two level of work experience (inexperienced and 5–10 years of experience) of the subjects were considered.

For both studies MAWL and its corresponding oxygen uptake) and BCF at L5/S1 (calculated using 3DSSPP) were taken as the dependent measures. A psychophysical method was used to determine the MAWL. This approach limits the workload based on the workers' perception of their lifting capability. It has been suggested that psychophysical methods are an integration of biomechanical and physiological loads (Waters et al. 2007). A psychophysical method has been widely used for evaluation of MAWL (Han et al. 2005; Lee 2005; Chen and Ho 2016; Wu 2000).

Table 1 Dimensions of the rectangular boxes

Type of box	Dimensions (L × B × D) (in cm)
Box 1	60 × 50 × 32
Box 2	70 × 50 × 24
Box 3	80 × 50 × 22.5

Table 2 Characteristics of subjects who participated in study-1 (N = 5)

Characteristics	Mean	Standard deviation (SD)
Age (years)	24.2	0.84
Height (cm)	170.8	6.14
Weight (kg)	67.9	5.2

Table 3 Characteristics of subjects who participated in study-2 (N = 30)

Age group (years)	Inexperienced			Experienced		
	Mean age (years)	Mean height (cm)	Mean weight (kg)	Mean age (Years)	Mean height (cm)	Mean weight (kg)
20–25	24.2	170.8	67.9	23.8	170.8	70.9
30–35	32.4	169.6	65.1	32.8	171.4	72.4
40–45	43	171.6	70.6	42.8	170.2	70.8
SD	8.15	4.45	5.92	8.2	3.85	3.81

2.1 Subjects

Five male subjects participated in the study-1. All subjects were healthy and had no history of back pain. Further, they did not have any past experience in the field of manual handling. Prior to the experiment, participants were informed about the procedure and possible risks involved and their consent was obtained. Trial runs were conducted to familiarize the subjects with the procedure (Table 2).

A total 30 subjects participated in the study-2, i.e. five experienced and 5 novice subjects in each of the three age groups (20–25, 30–35 and 40–45 years). As in study 1, all subjects were healthy and had no history of the musculoskeletal disorder. Prior to the experiment, they were informed about the procedure and possible risks and their consent was obtained (Table 3).

2.2 Experimental Task

A psychophysical methodology was adopted in this study. First, the subjects' weight and height were recorded. Participants were then asked to lift the rectangular box from the ground and place it on a platform 76 cm, high using both hands by holding the external handle provided. The frequency of lift was maintained at 4 lifts per minute. The start of experiment, and each subsequent lift was indicated by a buzzer. The total time for each task was 40 min, divided into two segments of 20 min each, with no rest period between the two (Fig. 1).

At the beginning of each segment, subjects were given a randomly selected box weight that was either very high or low. To avoid any visual cues, some weight was

Fig. 1 Subject performing lifting task

hidden in the false bottom. Subjects were aware of the hidden weight, but not its magnitude. They were encouraged to increase or decrease the load after every lift so as to arrive at the maximum weight that they may be able to lift for an 8-h period without getting exhausted. At the end of each segment, the weight was recorded using an electronic weighing machine (Everfest, Model REP 100 k; least count 10 gms). If the difference between weights selected in the two segments was within 15%, their average was recorded as MAWL. For larger differences, the reading was discarded.

Subjects then performed the same task for a period of 5 min lifting loads equal to their MAWL. Their oxygen uptake was measured using COSMED Fitmate MED pulmonary function equipment. Postures of subjects were used for calculating back compressive forces at L5/S1 disk.

3 Results and Discussions

Observations generated using the methodology described above were analyzed using two factor ANOVA. Results obtained are given below:

An ANOVA analysis at 5% significance level showed that box size had a statistically significant effect on MAWL for the lifting task undertaken in the present work (Table 4).

Results indicated that with increase in box length decrease in depth MAWL decreased. From a biomechanical perspective, increasing container length or width increases muscular strain due to a longer moment arm to shoulder or low back (Lee and Cheng 2011). Similar findings have been reported by earlier researchers. Ayoub and Mital recommended that increase in container volume should be accomplished

Table 4 Anova results for the effect of box size and handle position on mawl for subjects performing a manual lifting task

Source	df	MS	F	Sig
Box size	2	6.133	6.596	0.005
Handle position	1	7.803	8.392	0.008
Box size * handle position	2	1.183	1.272	0.298
Error	24	0.930		

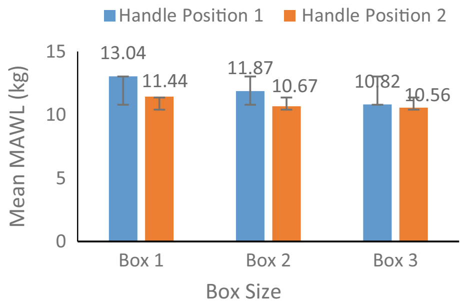

Fig. 2 Variation in mean MAWL with box size and handle position for subjects performing a manual lifting task

by first increasing its height, then its width up to a limit of 20 inches and finally its length to minimize the stresses on the back (Jung and Jung 2003) (Fig. 2).

It was observed that MAWL was higher for all box sizes when the handle was placed at 1/3rd of the box depth. When the handle was placed at ½ the box depth, the MAWL decreases by 6.73% and 7.69% for box 2 and 3, respectively (compared to box 1). The findings are in line with Mital and Fard's who reported a reduction of approximately 8.5% with change in handle position (Lee and Cheng 2011). While performing the task subjects complained of discomfort when the handle was placed at ½ the depth, because at this position a large portion of their wrist was in contact with the box. This exerted pressure on the wrist which lead to discomfort and hence a lower MAWL.

A significant change in MAWL with box dimensions did not, however, result in a statistically significant change in oxygen uptake and back compressive forces, or their interactions (Tables 5 and 6). This may be due to the fact that in the psychophysical

Table 5 Anova results for the effect of box size and handle position on oxygen uptake for subjects performing a manual lifting task

Source	df	MS	F	Sig
Box size	2	1.086	0.572	0.572
Handle position	1	0.481	0.253	0.619
Box size * handle position	2	0.604	0.318	0.731
Error	24	1.901		

Table 6 Anova results for the effect of box size and handle position on BCF (L5/S1) for subjects performing a manual lifting task

Source	df	MS	F	Sig
Box size	2	60,776.533	0.353	0.706
Handle position	1	74,600.533	0.434	0.516
Box size * handle position	2	11,670.933	0.068	0.935
Error	24	171,959.633		

approach participants can perceive the biomechanical and physiological stresses on their bodies and hence choose loads within their capabilities.

In the second set of experiments, the effects of age and work experience on MAWL were studied. Box 1 (60 * 50 * 32) with a handle at 1/3rd of the box depth was chosen for the study, as it resulted in maximum MAWL. Oxygen uptake (VO_2) and L5/S1 compressive force at MAWL were also recorded. The observations were analyzed using two factor ANOVA and the following results were obtained:

ANOVA results of the study show that the effects of age group and work experience were statistically significant for the MAWL (Table 7). However, the interactive effect of the two viz. age and work experience was found to be statistically non-significant for the lifting task under consideration.

As evident from Fig. 3, irrespective of age group, MAWL was higher for experienced subjects as compared to inexperienced ones. A decline in MAWL was seen for both experienced and novice subjects when age increases from 30–35 years to 40–45 years. Also, in case of experienced subjects, MAWL was least for the age group

Table 7 Anova results for the effect of age group and work experience on mawl for subjects performing a manual lifting task

Source	Df	MS	F	Sig
Age group	2	5.286	6.576	0.005
Experience	1	393.567	489.606	0.000
Age group * experience	2	1.038	1.291	0.293
Error	24	0.804		

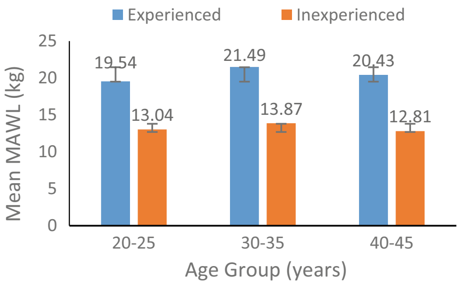

Fig. 3 Variation in MAWL with age group and work experience for subjects performing a manual lifting task

20–25. Inexperienced subjects, however, showed least MAWL for the age group 40–45 years. On the same lines, Gall and Parkstone concluded that older workers tend to maintain task-specific performance (Gall and Parkhouse 2004). Also, the results of the present study indicated that the MAWL, averaged across all age groups, for inexperienced subjects was 13.24 and 20.49 kg for the experienced group. The calculated RWL using 1991 revised NIOSH lifting equation for 8 h lifting duration and vertical height (V) $\leq$75 cm was 10.35 kg. This may point towards the conservative approach of RNLE as highlighted by previous researchers (Waters et al. 1993). However, since all subjects of this study were male, and RNLE encompassed both male and female workers, conclusive inferences cannot be drawn.

Age had a significant effect on MAWL. It was found that MAWL was highest for the age group 30 to 35 years. It first increased and then decreases as age group increased from 20–25 years to 30–35 years and then 40–45 years, respectively, for both inexperienced and experienced subjects. Age-related decline in functional capacity associated with impairments to the cardiorespiratory and muscular systems results in reductions in work output and ability to perform and/or sustain the required effort (Kenny et al. 2016). Chen et al. (2017) have reported that older workers selected lower load as compared to their younger counterparts. Sehl and Yates (2001) reported that after 30 years age, cardiovascular, respiratory and muscular systems may decline by as much as 2% per year. At age 30 years decline in cardiorespiratory fitness (commonly assessed by maximal oxygen consumption, VO_{2max}) begins (Sehl and Yates 2001; Fleg et al. 2005). The rate of decline may be 5%–15% per decade (Kenny et al. 2016; Crawford et al. 2010) or 0.25 to 1.04 mL/(kg * min * year) (Kenny et al. 2016; Gall and Parkhouse 2004; Savinainen et al. 2004) (Table 8).

ANOVA of the observations indicated that though age did not have a significant effect on oxygen consumption while performing a lifting task, the effect of experience was statistically significant. The two-way interaction between the variables was also found to be statistically non-significant for the experimental task (Fig. 4).

Experienced subjects showed a lower oxygen consumption as compared to inexperienced ones across all age groups (Table 9).

ANOVA on the data generated by the compressive force at L5/S1 showed that experience had a statistically significant effect on the lifting task under consideration. Effect of age, as well as the interactive effect of age and experience, was however statistically non-significant.

A bar graph (Fig. 5) plotted between compressive force at L5/S1 joint and experi-

Table 8 Anova results for the effect of age group and work experience on oxygen uptake for subjects performing a manual lifting task

Source	df	MS	F	Sig
Age group	2	0.157	0.095	0.910
Experience	1	12.160	7.325	0.012
Age group * experience	2	1.304	0.786	0.467
Error	24	1.660		

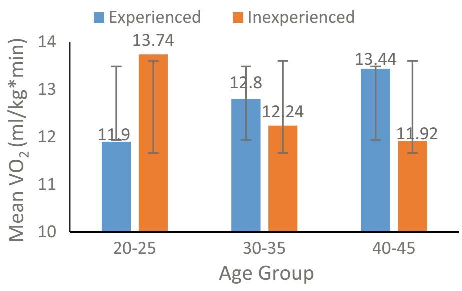

Fig. 4 Variation in oxygen uptake with work experience and age for subjects performing a manual lifting task

Table 9 ANOVA results for the effect of age group and work experience on BCF (L5/S1) at MAWL for subjects performing a manual lifting task

Source	Df	MS	F	Sig
Age group	2	22,302.700	0.157	0.855
Experience	1	600,529.633	42.294	0.000
Age group * experience	2	25,435.433	0.179	0.837
Error	24	141,875.317		

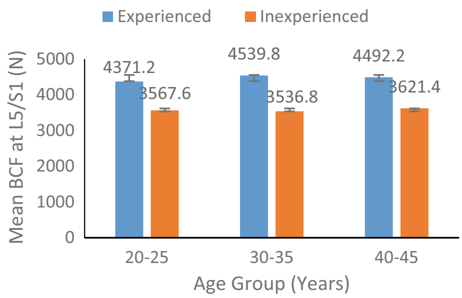

Fig. 5 Variation in BCF (L5/S1) at MAWL with work experience and age for subjects performing a manual lifting task

ence showed that experienced subjects had a higher mean compressive force (L5/S1) as compared to inexperienced ones for all age groups. Although there is very little literature available for the effect of experience on MAWL, the difference between lifting techniques of novices and experienced workers is well documented (Plamondon et al. 2014; Gagnon et al. 2000). Marras et al. showed that internal loading was greater for inexperienced subjects than experienced lifters over the course of an 8-h workday. They also opined that biomechanical risk is greatly reduced with experience (Marras et al. 2006). Plamondon et al. found that during a low lifting task, the external peak L5/S1 moments were similar but lifting posture of experts differed from novice workers (Plamondon et al. 2010). On the other hand, Lee and Nussbaum indicated that experienced workers used lifting/lowering methods with significantly higher peak lumbar moments (Lee and Nussbaum 2012). In another study, Plamondon et al. concluded that although experts had lower BCF than novices at higher heights, the peak resultant moment at L5/S1 was not significantly different from experts and novices (Plamondon et al. 2014). It is also important to note here that though most of the earlier literature compared BCFs of experienced and novice workers using similar loads, in the present study, the BCFs were calculated at MAWLs. Since MAWLs were higher for the experienced group they resulted in higher BCFs. Keeping in view the fact that the lifting techniques of experienced and inexperienced workers are different, further investigations need to be performed to predict the increase in risk, if any, due to the higher BCF.

In the present research L5/S1, compressive force at MAWL of 13.04 kg, 13.87 kg and 12.81 kg were 3567.6 N, 3536.8 N and 3621.4 N respectively for inexperienced workers. For experienced subjects, MAWLs were 19.54 kg, 21.49 kg and 20.43 kg with corresponding L5/S1 joint compressive forces of 4371.2 N, 4539.8 N and 4498.2 N, respectively. While the BCF were comparable to the recommended limits for novice subjects, they were much higher in the case of experienced ones. It is important to note here that the validity of 3400 N biomechanical criteria used in RNLE has been challenged by many researchers. Studies have revealed disc compression values between 2.5 and 8.0 kN (Elfeituri and Taboun 2002). Chen (2000) reported peak BCF (al L5/S1 disc) of 3300 ± 370 N, 4490 ± 520 N and 5050 ± 500 N when lifting a 5-kg, 15-kg and 20-kg loads, respectively, for subjects with an average mass of 67 kg. The mean of the BCF at L5/SI for average subject's mass of 67.5 kg ranged from 3272 to 5877 N (Abadi et al. 2016).

4 Conclusions

The present study established the effect of container size and handle position on MAWL for the lifting task under consideration. The MAWL decreased with increase in length and decrease in depth of the load. Between the two configurations studied, a handle placed at 1/3rd of container depth resulted in higher MAWL. Both age and experience played a role in performance of the manual lifting task considered. MAWL was found to first increase with age and then decline gradually. Also, while experienced subjects had higher MAWL, they were accompanied with significantly higher back compressive forces.

Further, it was observed that the back compressive forces (L5/S1) were consistently higher than the 3.4 kN limit of RNLE. Also, the RWLs obtained from the RNLE appear to be much lower than the MAWL obtained from the present study. This may point towards a conservative nature of the RNLE.

5 Future Scope

The significant effect of container dimensions indicates a need for and in-depth study of optimal dimensions of containers to provide guidelines for its design. In cases where use of optimal dimensions is not possible, other relief measures may be considered. Also, with the increase in life expectancy worldwide, the effect of age on task performance needs to be established and accounted for while deciding safe weight limits. Similar studies need to be conducted for female subjects. New multipliers may be added to the RNLE to accommodate non-optimal container dimensions, age and gender effects. This may be accomplished as either a lower recommended weight limit or lower frequency of lift.

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Chapter 24
Exploratory Study on Occupational Health and Work Environment Among Waste Management Workers in Kerala

Vinay V. Panicker and Francis J. Emmatty

1 Introduction

Solid waste management is one of the oldest concerns of humanity. The challenge of waste management has gained importance recently due to an increase in the generation of non-biodegradable and hazardous waste as a result of the industrial revolution. Waste management is one of the fastest-growing job sectors in the world (ILO 2012). Workers involved in solid waste management are exposed to occupational risks and injury rates higher than every other industrial occupation (UN-Habitat 2010; Çakit 2015). Waste management workers are usually inadequately remunerated, even in developed countries. Employees in the recycling branch have one of the maximum accident rates in Sweden (Engkvist 2010).

Workers in waste management stream are subject to high occupational health problems including musculoskeletal symptoms, respiratory, gastrointestinal and liver disorders and physical injuries (Emmatty and Panicker 2019; Yang et al. 2001). Workers are subject to various hazards due to lack of implementation of ergonomics including heavy lifting, manual handling, awkward positions and repetitive tasks, walking long distances, frequent whole-body vibration, manually packing waste in a container, handling of hazardous waste and lack of machines and lifting equipment (Engkvist 2010; Yang et al. 2001; Silva et al. 2005).

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Most of the occupational hazard studies among waste collection/sorting workers reported from India are concentrating on major cities. Questionnaire-based studies from India have been reported from Delhi, Mumbai, Chennai, Chandigarh and Kozhikode. The studies among municipal solid waste workers (Reddy and Yasobant 2015), waste collection workers (Singh and Chokhandre 2015; Chokhandre et al. 2017), and municipal waste loaders (Salve et al. 2017) reports musculoskeletal disorders in the lower back, knee, upper back and shoulder. These studies have tried to assess the causes for and the magnitude of such occurrences. Respiratory problems (Kandasamy et al. 2013; Ravindra et al. 2016; Ray et al. 2004) are identified among rag pickers, street sweepers, waste collectors, waste processors and the use of Personal Protective Equipment is recommended. Occupational injuries, self-reported musculoskeletal symptoms and exposure to toxic substances among household waste collectors such as aerosols leading to respiratory problems have also been reported in a study conducted in Taiwan (Yang et al. 2001).

Another survey and clinical examination conducted among women Municipal solid waste workers in Kozhikode, Kerala reports respiratory diseases, eye diseases, dermatological problems and nail infections (Jayakrishnan et al. 2013). The above study conducted at Kozhikode, Kerala focuses on community-based women workers. The inefficiency of SWM is mainly due to shortcomings of financial resources, workforce, transportation capacity and equipment (Kumar et al. 2009; Joseph et al. 2012; Sharholy et al. 2008).

In a country like India, the significant challenges when it comes to waste management are inadequate waste collection, transport, treatment and disposal methods. Government of India introduced Swachh Bharat Mission with the primary aim of alleviating the severity of these problems. As a preliminary measure, Swachh Survekshan was brought to the forefront, which is a survey study ranking different Urban Local Bodies (ULBs) based on their overall cleanliness. In this race of making ULBs better, the well-being of workers involved in waste collection/cleaning/segregation is also essential. Hence a discomfort survey to assess the overall well-being of the workers becomes the need of the hour.

Limited research has been found investigating the work environment of waste management workers in India; most of the previous studies are concentrating on occupational risks of waste management workers in a city. No research has been found investigating the occupational health problems among waste management workers in the various regions of a state in India. The present study aims to explore the work conditions of the waste collection workers in Kerala, including the nature of the job, tools and equipment used and the work environment. The study also explores the prevalence of various occupational health problems and the possible reasons for occupational risks. Through this exploratory study, we hope to shine some light on the well-being of the workers from selected regions around Kerala by identifying the various critical factors influencing their working conditions. This survey is a pilot study providing the groundwork for major work as a part of a funded project. The cause-effect relationships of occupational risks are not analyzed in the present research but found to be slightly correlated to general working conditions.

2 Methodology

After an extensive literature review, various factors affecting the overall well-being of the waste collection workers are formulated. An online questionnaire using Google forms was adopted for conducting face-to-face surveys with the workers. ULBs were selected from all across Kerala based on quota sampling as provided in Table 1. Initial interviews were carried out among 34 random subjects to ensure the validity of the questionnaire. Face-to-face surveys were conducted among 346 subjects across various parts of Kerala. The questionnaire was divided into six main sections:

- Demographic details
- Waste collection/sorting details
- Availability of tools and equipment
- Physical health assessment
- Physical environment and risks
- Psychosocial work environment and training.

2.1 Sampling Method

Quota sampling is a non-probability-based sampling technique which has been used in this study to arrive at the number of locations to conduct the survey study. 28 Municipalities and 2 Municipal Corporations were selected all across Kerala, spread across three zones. For the survey, Kerala has been divided into three zones: Malabar (North) zone, Cochin (Central) zone and Travancore (South) zone. The selection maintained the same ratio as the total number of municipalities to corporations in Kerala (87 Municipalities and 6 Municipal Corporations).

Table 1 List of urban local bodies selected using random sampling

Corporations	Municipalities		
	Malabar (North) zone	Cochin (Central) zone	Travancore (South) zone
Kollam Kozhikkode	Mukkam Koduvally Payyannur Ramanattukara Mattannur Anthoor Taliparamba Sreekandapuram Thalassery Vadakara	Thripunithura Maradu Kalamassery Eloor Chalakkudy Guruvayoor Irinjalakkuda Chavakkadu Vadakkancheri	Karunagappally Varkala Kayamkulam Attingal Kottarakkara Changanasserry Chengannur Thiruvalla Paravur

2.2 Geo-Tagging Technique

A study has used geo-tagging for data collection in epidemic outbreaks using smartphones (Farooq et al. 2016). Another comprehensive study has detailed information regarding usage of devices which supports geo-tagging features such as smartphones and tablets for questionnaire surveys (Zhou et al. 2014). The geo-tagging feature was incorporated into the Google forms using Google Script Editor. Global Positioning System (GPS)-enabled devices such as mobile phones and nts were used to insert metadata with geographical information (coordinates) in a file to specify the exact location. It could be viewed in Google sheet, and the data obtained will be further analyzed.

3 Results and Discussions

Various trends and observations were obtained from the aforementioned comprehensive study. The distribution of subjects based on gender is depicted in the adjoining pie chart representation, as shown in Fig. 1. The subjects belonged to diverse age groups, as shown in Fig. 2. Out of a total strength of 346, the significant represen-

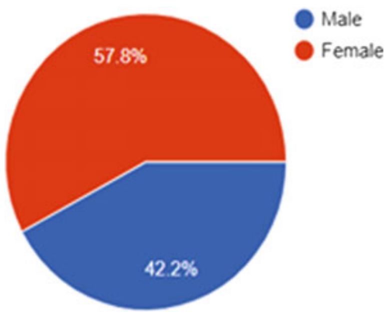

Fig. 1 Gender distribution of subjects

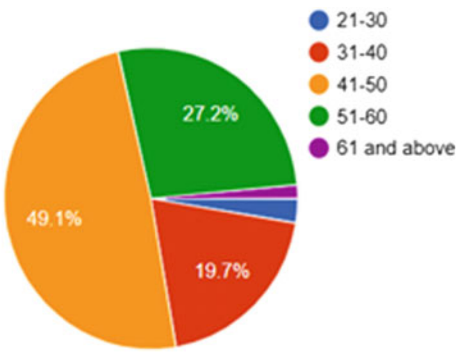

Fig. 2 Age distribution of subjects

Fig. 3 Tasks involved in waste collection

tation came from workers belonging to the age group of 41–50 years old. Almost 50% of the people fell in this group, hence being an essential factor in subsequent analysis.

The task of waste collection involved various activities including collection from roadside bins, door-to-door collection, street sweeping, waste picking and waste sorting, as shown in Fig. 3. One of the novelties noticed with regards to the door-to-door waste collection was in Taliparamba municipality. The authorities have developed a mobile phone application called "Nellikka" which have proved wonders for both the workers and the household owners. In this application, the phone numbers and associated details of all the members in a ward have been saved. This helps in effective communication as the household owners can be intimated well in advance in case of absence or delay in the collection on any particular day. Likewise, the workers can also be notified if there is nobody at homes, saving working time and avoiding unnecessary exertion.

The workers have to collect waste which has not undergone primary segregation, as shown in Fig. 4, which may lead to exposure to different kinds of hazardous materials. At many places, primary segregation is done at the point of the collection itself into biodegradable and non-biodegradable waste. In contrast, in some areas, all the waste is swept and piled together to be collected as a whole. These are subsequently sent to the segregation/treatment plants. In some places, where segregation plants are

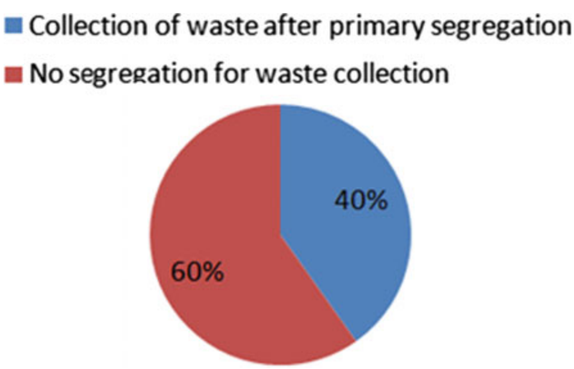

Fig. 4 Distribution of the quality of waste collected

far away and difficult to access, extensive dumping grounds are used where plastic wastes are separated. The workers working in such dumping grounds are likely to be susceptible to exposure because of the quantum of waste handled.

The type of container used for waste collection is shown in Fig. 5. It can be seen that workers are mostly using sacks for waste collection. Sacks and baskets are mainly used for collecting waste after sweeping or for loading to trucks, making the work more tedious and can be regarded as a significant contributor in developing musculoskeletal disorders. Most of the loading and unloading work which requires more energy expenditure was handled mainly by male workers.

The availability of personal protective equipment to the workers is shown in Fig. 6. Even though personal protective equipment is available, workers are reluctant to use them due to discomfort, difficulty in communication or low quality of the equipment. Significantly few workers reported inadequate provision of protective gear.

The use of various transportation means to transfer the collected wastes is given in Fig. 7. It can be seen that trucks are the most commonly used means of transport. Trucks are primarily used for bulk transportation of collected waste to segregation/treatment plants. At the same time, the intermediate short and medium distance transfer is done manually utilizing equipment such as carts, wheeled bins and tractors.

The various health problems faced by the workers are given in Fig. 8. Musculoskeletal disorders and respiratory problems are the major occupational health problems faced by the workers. These problems are discussed in detail.

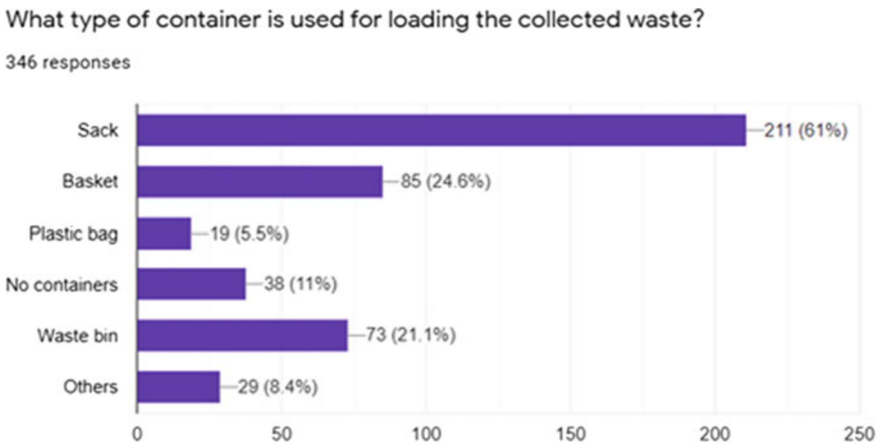

Fig. 5 Availability of containers for waste collectors

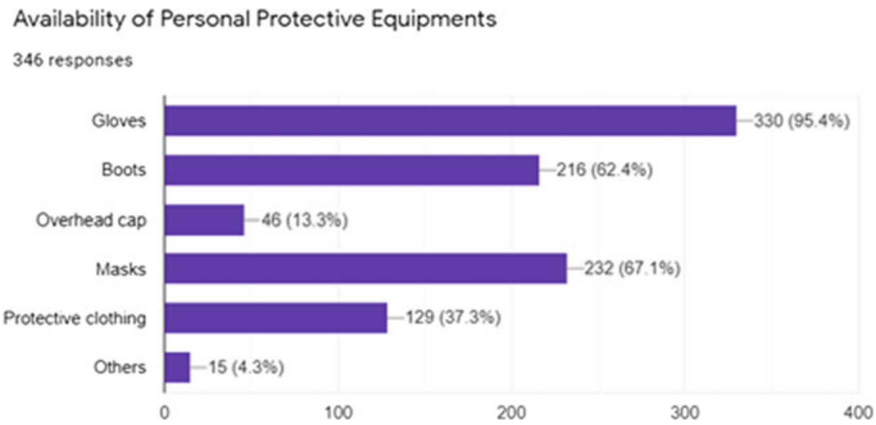

Fig. 6 Availability of personal protective equipment for the waste collectors

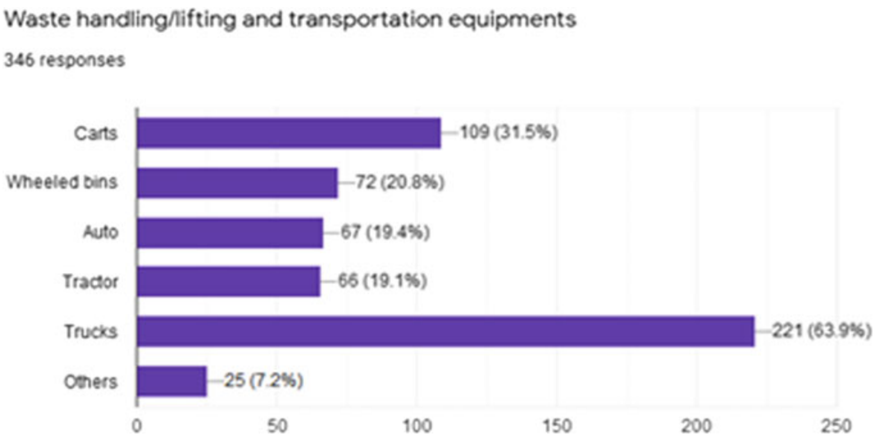

Fig. 7 Availability of transportation equipment for the waste collectors

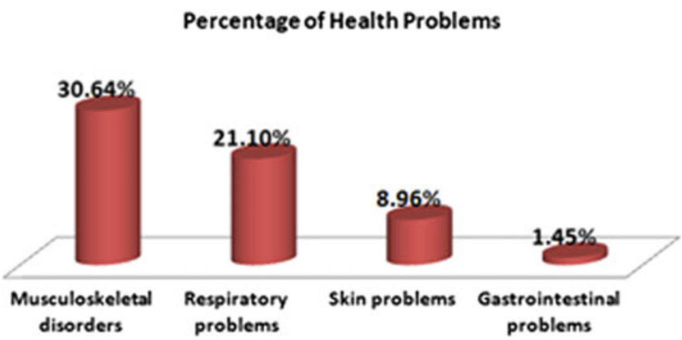

Fig. 8 Overview of health problems faced by workers

3.1 Musculoskeletal Disorders

Musculoskeletal disorders are found to be a prominent factor affecting the workers, and it was related to two different aspects—gender and age group. Overall, 106 workers reported musculoskeletal disorders out of 346 responses gathered, which accounts for almost 31% of the sample size.

Out of 200 females, 68 reported discomfort of any type whereas 38 out of 146 males reported pain in various body locations. These aggregate to almost 20% and 10% of the total responders for females and males respectively. It is seen that more women have shared their concerns about musculoskeletal disorders than men, the percentage of women being almost double that of men. This significant difference points out the role played by gender distribution. The higher percentage shows that women are more prone to such problems than men, which can be attributed to their anthropometric details.

When age is taken as the factor for comparison, different age groups were analyzed to the number of people from each age group who reacted positively to questions related to discomfort. On calculating each group's representation separately, it was found that 44 people who belonged to age group 51–60 reported difficulties. This amounts to almost 47% of the people in that age group. Other age groups have significantly lesser strength. Hence the age group is also taken as a decisive factor in developing musculoskeletal disorders, yielding the direct relation that the likelihood of developing these symptoms increases with increase in age. This is the main reason why a high percentage of subjects in the age group of 51–60 have registered a high percentage of musculoskeletal disorders.

3.2 Respiratory Problems

From the recorded sample size, 89 subjects reported problems such as respiratory issues, skin problems and gastrointestinal problems. Out of this, 73 were found to be affected by respiratory problems such as coughing and dust allergy. The contribution of the other mentioned problems was minimal when compared to respiratory problems when taken as a fraction of the sample size. Hence, this was taken as the factor to be investigated. Approximately, 21% of the total responders reported respiratory illnesses. For arriving at further unstated conclusions, respiratory problems were related to three factors- age group, gender and location.

From the aforementioned age distribution graph, there are 94 people belonging to the age group 51–60. Among these, 30 subjects reported respiratory issues, thus registering about 31% of the total in that age group. This turns out to be the highest count when each age group is taken individually. Thus it is concluded that this problem is most prevalent among the workers belonging to the age group of 51–60. Immunity power decreases with age, and this can be considered as the reason why subjects in this particular age group mostly report respiratory problems. Other age groups registered comparatively lower percentages. The age group which had the second-highest representation was 41–50, with 28% of the subjects belonging to the particular group having reported respiratory issues.

Concerning gender distribution, it was found that 45 females out of 200 and 33 males out of 146 reported respiratory problems, registering 22.5% in both cases. This indicates that men and women are equally likely to contract these problems, and hence no distinction can be made based on gender. This might be due to unsegregated collection of waste or general level of air quality and atmospheric pollution prevailing in the state.

It has been found out those subjects in Travancore zone predominate in the vulnerability toward respiratory problems. Approximately half of the subjects in the Travancore region have reported respiratory problems which is quite an alarming figure. The occurrence of the problem was most serious at Chengannur municipality where 13 out of 15 subjects who were interviewed reported such issues. 12% of subjects in the Cochin zone reported respiratory problems. Subjects in the Malabar zone reported the least occurrence of respiratory issues, approximately 5%. Hence, it can be inferred that the pollution levels and working conditions are very worse at Travancore zone. Malabar zone is very much better in these aspects as shown by the low percentage of persons with respiratory disorders.

4 Conclusion

Musculoskeletal disorders (31%) and respiratory problems (21%) are the significant occupational hazards faced by waste collection workers. It can be observed that workers are using sacks and other containers for transferring waste to transportation means like trucks. This might be one possible cause of musculoskeletal disorder for waste loading workers. The waste collected is not having primary segregation before collection, and may lead to a respiratory disorder. The non-usage of personal protective tools like masks and gloves will expose workers to various hazards. The quality of tools and equipment, PPEs provided to these workers should be ensured. The present research will provide an outline for identifying the root causes of occupational risks for taking preventive measures.

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Chapter 25
Foot Impairments and Overuse Injuries in Long Distance Runners—A Prospective Study for the Prevalence

G. Vijayan and K. Murali Rajan

1 Introduction

Running is considered one of the most accessible sporting activities, in terms of cost and ease of implementation and the number of athletes from recreational to elite levels is growing as running can be done everywhere and by almost everyone (Fredericson and Misra 2007). Covering more than 3000 m in a single session is considered as long distance running and is often recommended to maintain a healthy lifestyle (Shipway and Holloway 2010). Though the positive effects of running on cardiovascular risk factors, mental and social aspects are well known, running is not an activity without risk and has also been associated with musculoskeletal injuries (Taunton et al. 2002). The number of studies assessing the prevalence of injuries in runners has been increasing (Schueller-Weidekamm et al. 2006).

The prevalence of musculoskeletal pain in long distance runners who compete at the elite level is unclear despite several studies that have been conducted on running injuries. Previous studies of overuse injuries in long distance runners have been limited by a retrospective study design or by a short duration and small sample size. This is important information as it represents the first step in the sequence of prevention research (Aicale et al. 2018).

Acute running injuries are rare, consisting mainly of muscle injuries, sprain, or skin lesions (blisters and abrasions) (Hreljac 2004). Eighty percent of running disorders are overuse injuries, resulting from a mismatch between the resilience of the connective and supporting tissue and running with an incidence proportion of 96% (Hoeberigs 1992). The predominant site of leg injuries is the knee, for which the location-specific incidence ranged from 7.2 to 50.0%. Running injuries of the lower

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leg, foot and upper leg are common, ranging from 9.0% to 32.2%, 5.7% to 39.3% and 3.4% to 38.1%, respectively. Less common sites of running are the ankle, the hip/pelvis/groin and lower back, ranging from 3.9% to 16.6%, 3.3% to 11.5% and 5.3% to 19.1, respectively (Hreljac 2004).

Overuse injuries are defined as 'those without a single, identifiable event responsible for their occurrence' (Yang et al. 2012). They occur as a result of accumulated stress on tissues such as ligaments, bones and tendons. While the specific tissues and anatomical sites involved vary from one individual to another, the cause is the same, repeated episodes of microtrauma surpassing the body's ability to repair (Herring and Nilson 1987). The absence of a single, identifiable traumatic cause has been traditionally used as a definition for a causative factor of overuse injury. Excessive loading, insufficient recovery, and under-preparedness can increase injury risk by exposing athletes to relatively large changes in load. The musculoskeletal system, if subjected to excessive stress, can suffer from various types of overuse injuries which may affect the bone, muscles, tendons and ligaments (Aicale et al. 2018; Worp et al. 2015).

Foot impairments, as a potential lower extremity overuse injury risk factor, has received great attention in research and clinical practice. The possible causes of the symptoms, such as abnormal biomechanics of the ankle and foot should be given main attention rather than the treatment of most painful site (Tschopp and Brunner 2017). It has been difficult to verify the casual relationship between a specific type of malignant and a specific injury (Worp et al. 2015). Different types of foot structure have shown to be an important factor in plantar pressure distribution pattern. Any inappropriate plantar pressure distribution may increase the risk of tissue injuries leading to be a source of pain (Jakobsen et al. 1994). Running, being a closed kinematic chain activity, the interaction between the foot and the ground determines the probability of injury occurrence in this area (Shipway and Holloway 2010).

The objective of this 6 months prospective cohort study was to record the prevalence of overuse injury, and to find out the location, severity of running-related musculoskeletal pain and injuries among long distance runners preparing for a major marathon event. No previous similar studies have been identified from the current evidence base and hence this study presents a unique opportunity to establish a platform for identifying runners at risk and designing injury prevention programs.

2 Methods

The purpose and methods of study were explained to the office bearers of two runners' groups which were subsequently informed to the members through their WhatsApp and Telegram group to ensure the participation of its members. All runners who fulfilled the selection criteria were recruited from two runners' clubs in Ernakulum district, Kerala during the period September 2019 and February 2020. The runners between the age group of 18–60 from both genders were recruited. The runners who had met with any injury of lower limb or spine, runners who underwent any surgery or procedure within a period of last 6 months, the runners who already are taking treatment for any kind of overuse injuries and the runners who use any footwear modifications were excluded from the study. They were met and evaluated by the investigator during their regular training sessions.

All runners who agreed to participate in the study gave written informed consent prior to enrolment. The study protocol was approved by the local institutional ethics committee in accordance with guidelines for research involving humans.

To assess the prevalence of musculoskeletal pain over the previous 12 months, the runners were verbally interviewed about the presence of musculoskeletal pain. Next, the runners scored the pain intensity, using a numerical analogue scale ranging from zero (no pain) to ten (intolerable pain). According to the reported score, the pain intensity was classified as mild (1 or 2), moderate (3–7), or intense (8–10). All information was obtained through direct verbal interviews conducted by the investigator. The Oslo Sports Trauma Research Center questionnaire (Clarsen et al. 2014), which can be applied to find overuse injuries in any anatomical area, was also used (after modifying to the need of the present study). This questionnaire was used to collect data on injuries located in the ankle and foot, knee and leg and low back, hip and thigh and to guide the diagnosis and to record the severity. These areas were selected for this study as previous studies of long distance running injuries have suggested that these are the most common sites of injury among such runners. There were four questions for each anatomical area that covered symptoms, and the consequences of these upon training volume, performance and pain during running. The possible symptoms for each anatomical area were outlined before starting the questions so that there was no ambiguity. Ages of the runners were recorded in the proforma which was extracted and categorised to find out the correlation between age and overuse injuries (less than 25, 26–30, 31–35, 36–40 and 41+ years). Also, the runners' total years of experience in running was recorded and categorised (less than 1, 1–5, 6–10 and 11+ years).

The runners' feet were physically examined for the presence of any anatomical impairments. They were also interviewed about the usage of any footwear modifications to avoid difficulties during the running.

The participants were given the study information leaflets which also contained the contact details of the investigator and instructed them to report the onset of any new overuse injuries. Such runners were met personally on a mutually convenient time and the data were obtained.

From the data collected from the runners, prevalence of the issue was identified category wise and the runners with most prevalent overuse injury were selected for shoe modification. The shoe modification was done based on the anatomical impairment and the functional difficulty of the runners. They were instructed to wear the modified running shoe during their routine practices and while participating in the running events. They were frequently contacted through WhatsApp or text messaging to ensure their compliance in the usage of modified footwear. They were re-evaluated after 6 months of modified footwear usage, and the outcomes in terms of pain and functional ability were recorded.

The other runners who had pain and functional difficulties were managed with the exercise programs specific to the respective overuse injury.

3 Data Analysis

3.1 Prevalence Calculations

Prevalence was calculated by adding all runners who reported at least one overuse injury during the study period and dividing by the total number of participants in the study. The term 'significant problems' refers to those overuse injuries that led to reduced participation or inability to participate.

The data were analysed using the SPSS Version 22.0 for Windows. Chi-squared tests were used to assess the relationship between overuse injuries and players' age, experience and the foot impairments.

4 Result

The average prevalence of overuse injury problems in all the anatomical locations was 65.52%, (Table 1), with 25% of runners reporting significant overuse injuries, causing enough symptoms to reduce or prevent participation (Table 2). A breakdown by anatomical area also is seen in Table 2.

The largest percentage of runners with overuse injuries fell in the age group of 36–40 years (35.96%). Table 3 illustrates the age group of runners with overuse injuries having foot impairments. The 81.4% of runners with any kind of foot impairments

Table 1 Prevalence of overuse injuries

	All	With overuse injuries (%)	Without overuse injuries (%)
Gender	161 Males	110	51
	13 Female	4	9
Total	**174**	**114**	**60**

Table 2 Overuse injuries based on the anatomical locations

	Ankle and foot	Knee and leg	Low back, hip and thigh	Total (%)
Overall prevalence (%) (all problems)	40.11	19.46	5.95	65.52
Overall prevalence (%) (significant problems)	10.21	4.87	1.49	16.57

Table 3 Age group of runners with overuse injuries having foot impairments

Age group	Runners with overuse injuries having foot impairments (35)	Runners with overuse injuries not having foot impairments (79)
<25	2	6
26–30	4	11
31–35	10	24
36–40	12	29
>41	7	9

Table 4 NPRS of pain in runners with overuse injuries

NPRS	Runners with foot impairment	Runners without foot impairment
Mild (1–2)	6	20
Moderate (3–7)	26	48
Severe (8–10)	3	11

reported presence of overuse injury and the percentage of prevalence of overuse injuries in runners without foot impairments was 60.31%.

Severity of overuse injuries was assessed by means of pain status measured by numerical pain rating scale (NPRS) and shown in Table 4.

The common foot impairments observed in runners were flat feet, hallux valgus, overpronated feet and pes cavus with runners with flat feet at large. The number of runners with each foot impairment is tabulated in Table 5.

Plantar fasciitis was the most prevalent overuse injury found in these long distance runners. Table 6 depicts the number of runners with various overuse injuries among long distance runners.

Most had been running for more than 6–10 years (61.1%) and the injury rate was found to be lower in this group. Unsurprisingly, those with the least experience (1–5 years) had the highest injury rate in every anatomical area (Table 7).

As all the runners with plantar fasciitis had the anatomic impairment of flat feet, they were given prefabricated shoe insoles with medial arch support. These insoles come with standard footwear sizes. The runner has to use shoes with one size bigger than their actual foot size in order to accommodate this insole comfortably inside. Table 8 shows the dependent ‘t’ test performed with pre and post-test values of pain

Table 5 Prevalence of foot impairments

Common foot impairments observed	No. of runners (43)
Flat feet	28
Hallux valgus	3
Overpronated foot	9
Pes cavus	5

Table 6 Overuse injuries observed among long distance runners

Common overuse injuries observed	Runners with foot impairments (43)	Runners without foot impairments (131)
Plantar fasciitis	24	42
Medial tibial stress syndrome (Shin splints)	7	10
Achilles tendinpathy	2	15
Patellofemoral pain	1	7
Iliotibial band syndrome	1	5

Table 7 Number of years in running experience and overuse injuries

Number years of training/running	Total runners (174)	Runners with overuse injuries having foot impairments (35)	Runners with overuse injuries not having foot impairments (79)
1–5 years	28	23	49
6–10 years	112	7	10
11 + years	34	5	20

Table 8 Dependent 't' test performed with pre and post-test values of pain using numerical pain rating scale

Variable	't' cal value	't' table value
Pain	13.043	1.761

't' calculated value > 't' table value, Significant at 5% level

using numerical pain rating scale which shows a significant difference in the pain status of runners.

5 Discussion

This study is, based on the current available literature, the first of its kind looking exclusively at overuse injuries in long distance runners. The major findings were that, at any given time during the course of the study, more than half the cohort (65.51%) were suffering from some form of overuse injuries and 16.6% of runners had overuse injuries causing a moderate to severe reduction in training participation or sports performance, or complete inability to train (significant overuse problems). This suggests that the magnitude of overuse problems in long distance runners is high, supporting the conclusions of previous reports (Shipway and Holloway 2010; Tschopp and Brunner 2017; Worp et al. 2015).

Three specific anatomic areas were investigated in this study: ankle and foot, knee and leg and low back, hip and thigh. While overuse symptoms were prevalent in all locations, the ankle and foot were the areas with the highest prevalence of substantial problems (40.11%). The most commonly diagnosed type of overuse injury was plantar fasciitis (37.93%).

The highest reported injury prevalence rate of injuries in the current literature is 60.11% (Aicale et al. 2018). Given that overuse injuries were identified in 65.51% of this study cohort, overuse injuries should be majorly considered in designing injury prevention programs.

One of the main findings of this study was that injuries in ankle and foot were more prevalent than other areas like knee and leg or thigh, hip and low back, which supports the premise that long distance running is a ‘game prone to ankle and foot injuries’ (Robbins et al. 1993; Hootman et al. 2002; Alfredson and Lorentzon 2000). This agrees with multiple studies (Aicale et al. 2018; Gallo et al. 2012; Milgrom et al. 2003). However, they did not differentiate between acute and overuse injuries.

If an overuse injury is ‘characterised by a mechanism of gradual onset and an underlying pathogenesis of repetitive micro trauma’ there should be an increase in these injuries over the course of the training and participation (Mechelen 1992).

There were a number of significant findings in this study, which could be used to develop sport-specific injury prevention programs. For instance, both ankle and feet injuries were more common in less experienced players. This contradicts one study, which found that young elite players were more at risk of injury (Milgrom et al. 2003; Andrish et al. 1974). However, other studies agree that players aged over 30 years are at the greatest risk (Hootman et al. 2002).

Interestingly, those runners who have foot impairments had significantly more overuse injuries. Though it is difficult to establish the cause and effect here it could be due to the biomechanical changes during the different phases of foot–ground interaction and the difference in impact felt in the soft tissues of foot as against the normal foot (Lieberman et al. 2010; Ryan et al. 2009; Robbins et al. 1993; Crowell and Davis 2011; James et al. 1978). Also the insole which was used to support the impairment was found to be very effective as the biomechanical changes were brought back to normal and thus reduced the impact felt in soft tissues of foot.

6 Conclusion

The prevalence of overuse problems in long distance runners is high, with most prevalent sites of injury being the ankle and foot. Our findings were consistent with similar studies done previously. The shoe modification done with prefabricated insoles were found to be very effective in managing the plantar fasciitis in runners with flat foot. Future injury prevention studies in long distance runners should focus on these areas.

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Ethical Clearance Institutional Ethics Committee, Rajagiri Hospital.

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Conflict of Interest Nil.

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Chapter 26
Grid-Based Blind Spot Analysis for Indian Driver Anthropometry

G. Rajkumar and K. Ratnakumar

1 Introduction

Blind spot is the area around the vehicle where the driver will not have an access of visibility. Vehicle such as bicycle and two wheelers have zero blind spot. The problem arises only with respect to the four wheelers. In four wheelers the vehicle's A pillar, B pillar and C pillar along with the vehicle body act as a source of obstruction to the driver. Nowadays Vehicle Design, Development and fabrication has huge challenges and complication. A successful design should satisfy all multidimensional needs of the product (Vehicle). Design and development of Automobile is one such task where Human factors and driver ergonomics should be given equal weightage along with aesthetics, performance and emission, etc. The design needs should include ergonomics along with operational needs, functional needs and performance needs of the vehicle. The best vehicle design is that it should satisfy all the operational, functional and performance characteristics for the user (in our case it is driver). Ergonomic Evaluation of Automobile is an interesting area where it directly contributes to the safety[1]. The Driver ergonomics in a notable research area to understand the various shot comes the driver undergoes due to different driving environment. The process is same as a man–machine integration with the changing environment. The performance of the driver purely depends upon how well these interactions are made with respect to the environment.

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[1] http://mospi.nic.in/statistical-year-book-india/2018/189

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2 Road Accident in India

India is one of the rapid growing market for automobile in the world this intern question about the infrastructure requirements to handle such huge population of vehicles. India has a capacity of five lacks and sixty thousand kilometer of road infrastructure as of 2016 (Fig. 1).

According to the report from ministry of statistical program there are over 23 crore vehicles are sold in the year of 2016 (http://mospi.nic.in/statistical-year-book-india/2018/189)(Ball et al. 2007) and implementation Recent Statistics says to know that Bangalore stands top in the highest traffic congestion city in the world (https://economictimes.indiatimes.com/news/politics-and-nation/bengaluru-is-the-most-traffic-congested-city-in-the-world-report/articleshow/73734530.cms?from=mdr) (Gunasekar and Chandramohan 2018). Finally, the total no of life lost and injured due to road accidents in 2016 is around six lacks. All this statistic clearly states the importance of safety standards of vehicle and infrastructure (Fig. 2).

According Society of Indian Automobile Manufacturers cars are segmented based on their length. It is found that vehicle under the segment A2 and A3 have the highest no of sales in India due to its affordability. A study has been carried out to gather the information related to top selling vehicle and found that it was Vehicle A, Vehicle B and Vehicle D which were at consistency peaks of the sales for the year of 2016, 2017 and 2018 which falls under A2 and A3 category. Since these category vehicles are low cost segment and not provided with many high-end sophisticated safety

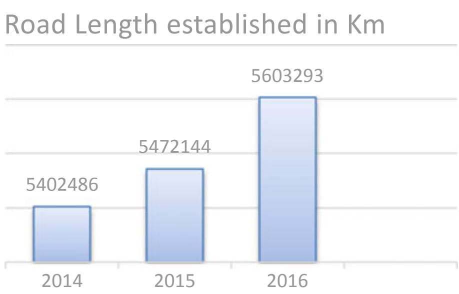


Fig. 1 Source open government statistical data on rate of road in fracture developed

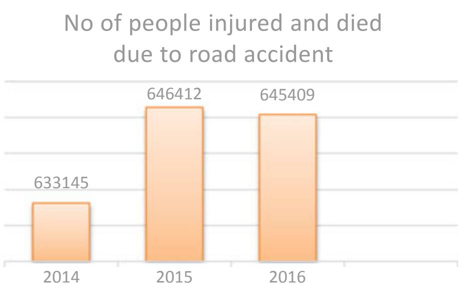


Fig. 2 Open government source statistical data on no of people injured and died

Table 1 Vehicle segmentation based on siam

Car segment	Length of the car
A1	Up to 3400 mm
A2	3401 to 4000 mm
A3	4001 to 4500 mm
A4	4501 to 4700 mm
A5	4701 to 5000 mm
A6	More than 5000 mm
B1	Vans
B2	MUV/MPV

features. Thus, the 360° grid-based analysis technique is carried out on these vehicles and safety enhancement for visibility improvement is fixed and tested to reach out maximum population (Table 1).

3 Automotive Driver Ergonomics

The vehicle driver is a trained person used to operate a vehicle. There are various factors related to driver ergonomics such as accommodation, Sitting comfort, Reachability, Visual field and Obstruction. This study is focused on Visual field obstruction and its disadvantages. The vehicle driver should have a good view of the vehicle outside environment to understand and react during different driving conditions. Most of the viewing angles are interlinked with the seating position of the driver hence there are SAE-J1517 standards that have been established for seat design and positioning[2]. The driver cabin design is the linkage between integrating the vehicle interior with exterior, this should be done to obtain maximum driver visibility for safe operation. Deeper understating of human vision is required to take out this challenge (Fig. 3).

Human being has binocular field of vision. The 360° field view can be classified into two types direct field of view and Indirect field of view (Hashim et al. 2018). The Object which is under direct visibility without any head rotation required is called direct field of view, hence all the basic control and infotronics are provided in this area such as windshield, speedometer, fuel level indicator, etc. The two-side mirror and rear-view mirror are provided to produce maximum visibility on Indirect Field of view. Put together the safe driving complete depends upon sum of direct and indirect field of view (Fig. 4).

Based on this assumption the 360° field of view mapping is created to plot down the grids. The development of grid is also done by considering the Indian road lane width. The three lane model is followed to understand the complete FOV as on road

[2] https://economictimes.indiatimes.com/news/politics-and-nation/bengaluru-is-the-most-traffic-congested-city-in-the-world-report/articleshow/73734530.cms?from=mdr

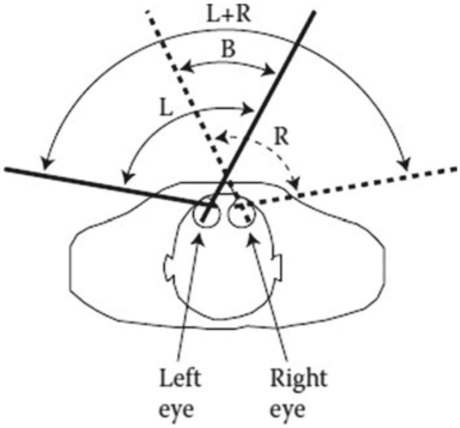


Fig. 3 Left monocular (L), right monocular (R), binocular (B), and am binocular (L + R) fields. The picture represents a plan view of the driver and horizontal fields of the left (L) and the right (R) eyes

condition. The test was carried out with South Indian ethnic 5th Percentile female and 95th Percentile male who were chosen as lower and upper limit for ergonomic testing. The Anthropometry data were measured in the lab. The sitting height and standing height were measured for both 5th and 95th percentiles (Fig. 5 and Table 2).

4 Blind Spot Analysis Using 360° Grid-Based Technique

Blind spot is defined as an area outside the vehicle with which a driver can't able to see through. This area is so specific it doesn't cover in the rear and side view mirror. Objects coming inside this blind spot are most viable to accident during driving since driver will not have the visibility access. The main contributor to the vehicle blind spot is the vehicle body parts such as A, B and C pillar with which the vehicle roof is supported. These pillars are unavoidable in the chassis construction. The thickness of the pillars is designed to provide maximum visibility and required roll over strength. The Grids are developed based on the road width from National Highway Authority of India. The width of a particular lane is found to be 3.5 m hence tow grids or 3.5 m are placed on either side of the vehicle the length of the grid is finalized as 4.5 m. The grid is placed along all the four quadrants around the vehicle to understand the direct and indirect view of the driver which represents the road lanes. The test cone is used as an detecting object which has an height of about 750 mm (Fig. 6).

Each grid was set to 500 mm × 500 mm. The area covered was 3500 mm × 4500 mm for each side of the vehicle, which was sufficient to determine the zone by considering Indian anthropometric data. The total No of Grid on One side: 63 nos (Fig. 7).

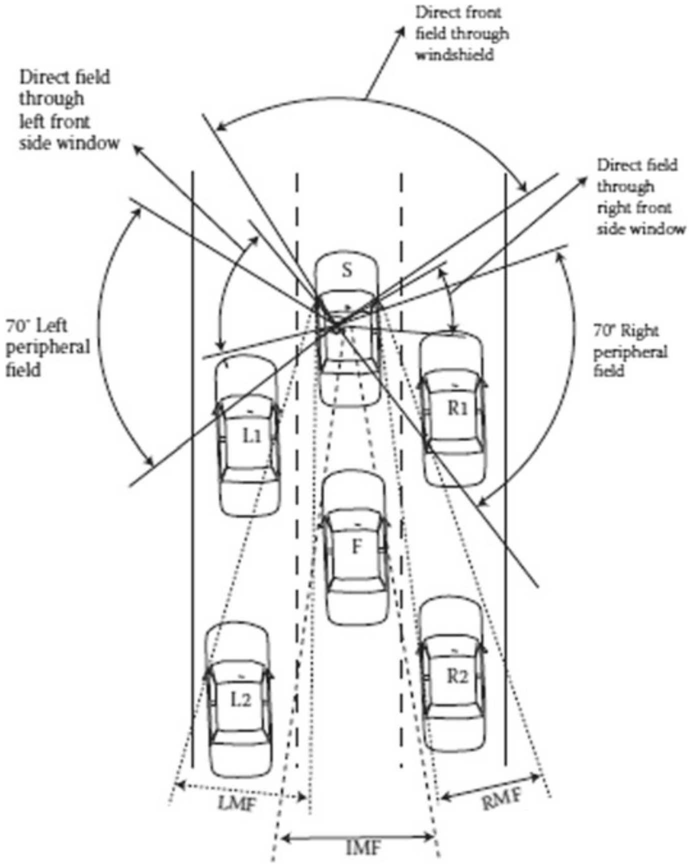


Fig. 4 A 360° visibility from direct, indirect, and peripheral fields

Grid size	0.5 m × 0.5 m	0.25 m^2
One side area covered	3.5 m × 4.5 m	15.75 m^2
360° grid	2 (3.5 m × 4.5 m)	31.5 m^2

Fig. 5 5th Percentile female sitting and standing height and 95th Percentile Male sitting and standing height

Table 2 5th Percentile female sitting and standing height and 95th Percentile Male sitting and standing height

	5th Percentile Female (cm)	95th Percentile Male (cm)
Sitting height	105	135
Standing height	155	185

The side view camera device is used to fix under the rear-view mirror to stream the video direct inside the drivers cabin using the LCD screen mounted near the A Pillar. This system is power for the vehicle battery so no dedicated power source is required to operate the system.

Specification of Gear Six all weather night vision camera *Model: Gear six side view camera* *Manufacturer: Gear six* *Special features:* *LED Night Vision* *170° Wide Angle* *Water Resistant*	**Specification of the LCD display**: Model: S-RVM 4.3″ MONITOR Manufacturer: S-RVM Features and specification: Screen size: 4.3″ TFT-LCD Digital Panel Screen Format: 4:3 Resolution: 480 * 272 Colour System: NTSC/PAL/Auto Selection A/V Input: 2 Dimension: 300 mm * 20 mm * 88 mm

The camera is grilled to the down side of the rear view mirror. The positioning is provided in such a way to provide maximum visibility coverage since the coverage angle was around 170° which gives us an advantage to cover the blind spots. Hence the system is capable of working in all-weather conditions and also night vision

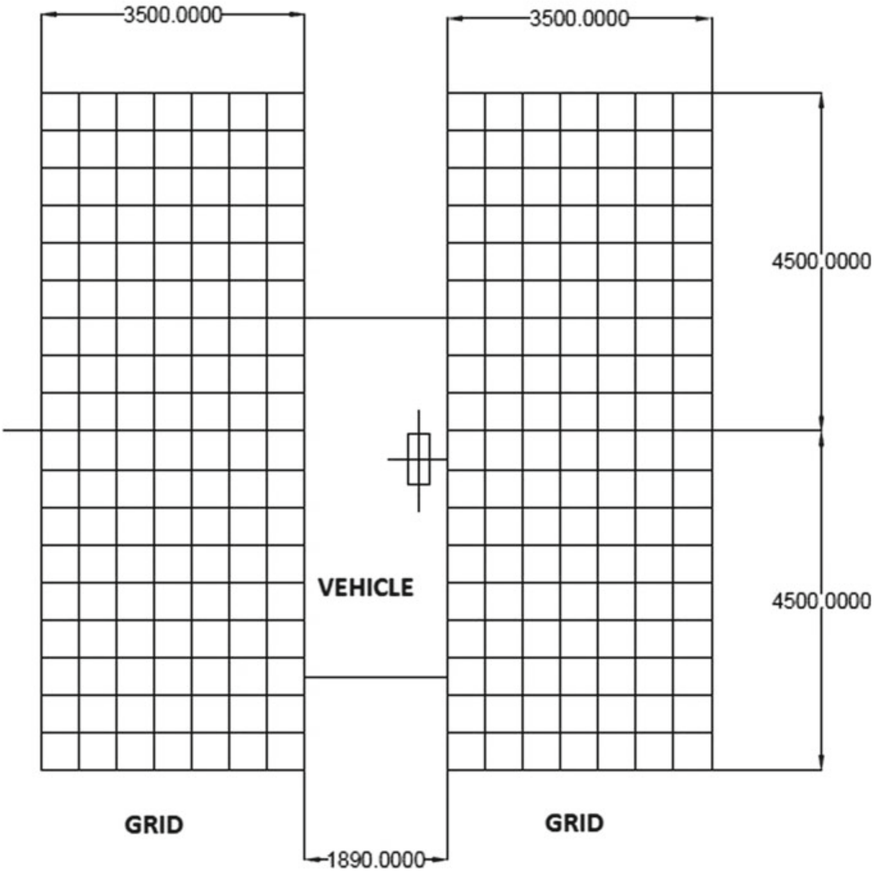


Fig. 6 Four quadrant grid design

capabilities it has an advantage of providing clear indirect view to the driver around the vehicle. This make the driver more informed about the vehicle's environment. To get a precise understanding of this factor the 360° grid-based analysis is carried out and the visibility parameter is measured in terms of area of the grid (Fig. 8).

Blindspot Testing—Vehicle A–A2 Segment

The 360° blind spot analysis has been carried out for Vehicle A–A2 Segment. The blind sport region of the 5th percentile female and 95th percentile male is measured. Found vison status improvements after the induction of the all-weather night vision camera. It is also found that the rear blind spot area has been drastically reduced when compared to the earlier one (Fig. 9).

Fig. 7 Cloth grids fabricated

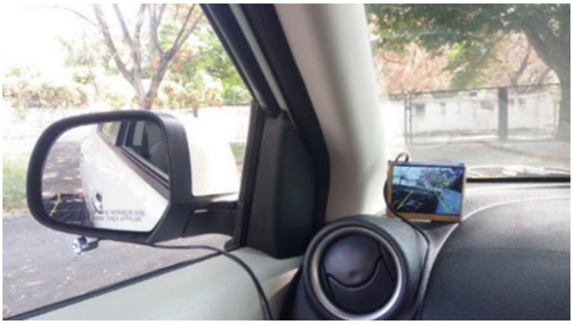


Fig. 8 Installation of Rear-view camera to the vehicle

Fig. 9 Blind spot measurement for Vehicle A

Blindspot Testing—Vehicle B–A2 Segment

The 360° blind spot analysis has been carried out for Vehicle B–A2 Segment. The following tables shows the blind sport region of the 5th percentile female and 95th

Fig. 10 Blind spot measurement of Vehicle B

percentile male and found vison status improvements after the induction of the all-weather night vision camera. It is also found that the rear blind spot area has been drastically reduced when compared to the earlier one (Fig. 10).

Blindspot Testing—Vehicle C–Segment A3

The 360° blind spot analysis has been carried out for Vehicle C–Segment A3. The following tables shows the blind sport region of the 5th percentile female and 95th percentile male and found vison status improvements after the induction of the all-weather night vision camera. It is also found that the rear blind spot area has been drastically reduced when compared to the earlier one (Figs. 11, 12 and Table 3).

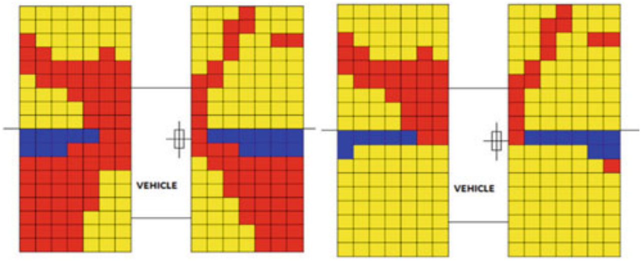
Fig. 11 Blind spot measurement of Vehicle C

Fig. 12 Grid-based blind spot measuring setup

Table 3 Blind spot area and visibility area table

Sl. No		Percentile	Total area (Square meter)	Blind spot area (Square meter)	Visibility area (Square meter)	Percentage of blind spot area (%)	Percentage of visibility area (%)
1	Before camera	5th Percentile	63	28.5	30	45.2	47.6
2	After camera	5th Percentile	63	11	48.5	17.5	77
3	Before camera	95th Percentile	63	23.5	34.25	37.3	54.4
4	After camera	95th Percentile	63	5.25	54	8.3	85.7
5	Before camera	5th Percentile	63	21.25	35.75	33.8	56.7
6	After camera	5th Percentile	63	3.5	55.5	5.6	88.1
7	Before camera	95th Percentile	63	18.75	37.75	29.8	59.9
8	After camera	95th Percentile	63	2	57	3.2	90.5
9	Before camera	5th Percentile	63	27.5	31	43.7	49.2
10	After camera	5th Percentile	63	8	51.5	12.7	81.8
11	Before camera	95th Percentile	63	21.25	36.5	33.7	58.7
12	After camera	95th Percentile	63	4.25	55	6.7	87.3

Vehicle A - A2 Segment – 5th Percentile



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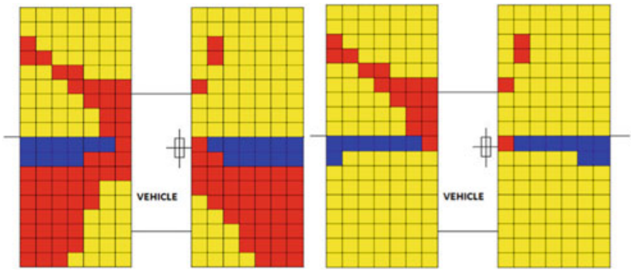
Vehicle A - A2 Segment – 95th Percentile



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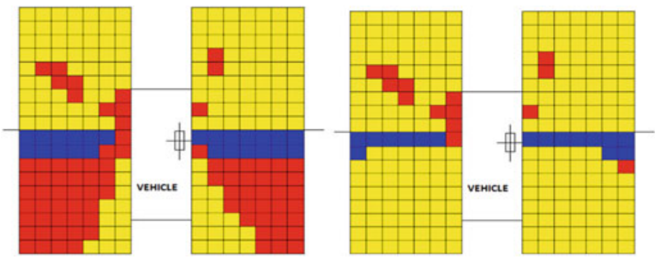
Vehicle B - A2 Segment – 5th Percentile



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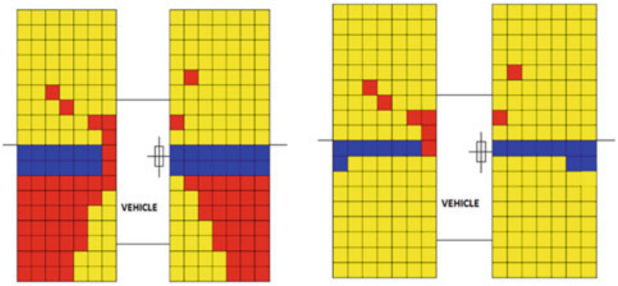
Vehicle B - A2 Segment – 95th Percentile

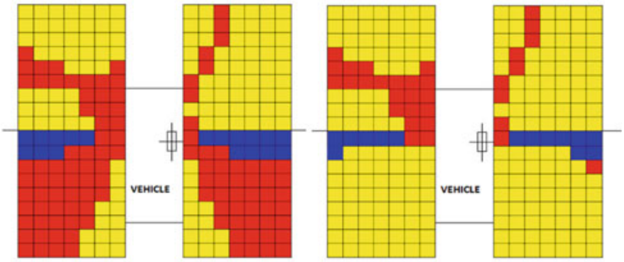


Without Camera with camera

BLIND SPOT MAPPING

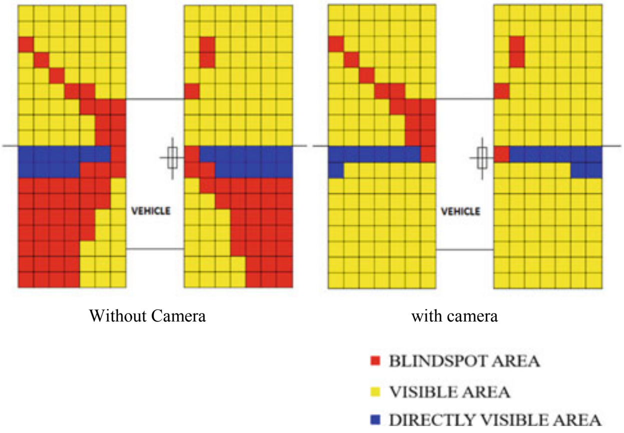
- BLINDSPOT AREA
- VISIBLE AREA
- DIRECTLY VISIBLE AREA

Vehicle C – A3 Segment – 5th Percentile



Without Camera with camera

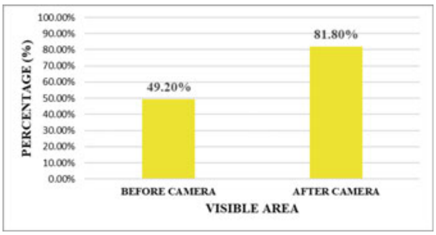
Vehicle C – A3 Segment – 95th Percentile



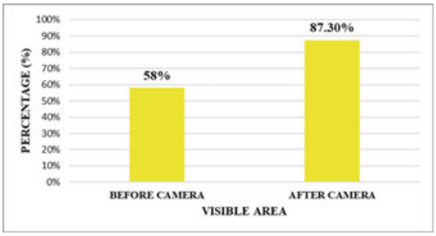
4.1 Results and Discussion

According to the results of blind spot, experimented using grid-based technique on three segment cars (A2 and A3), it was found that the area behind the side mirror contributes more blind spot regions for both 5th percentile female and 95th percentile male. For higher segment cars, various system has been adopted to reduce blind spot zones. In Indian markets, A2 segment cars are highly preferred. For these types of lower segment cars, blind spot detection systems are not given much importance which leads to accidents. By addressing these problems, an side view camera is adopted in the behind of side mirror with LCD display in dashboard for ergonomic view of driver. By adopting this system, the blind spot area is minimized drastically. The recovery area of blind spot area to visible area for three segment cars on 5th and 95th percentile is shown.

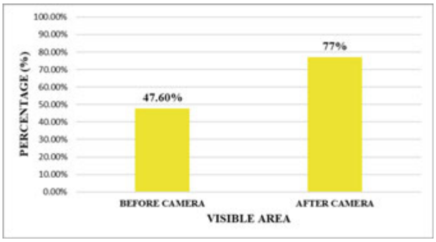
Blind Spot Reduction in 5th Percentile A3 Segment



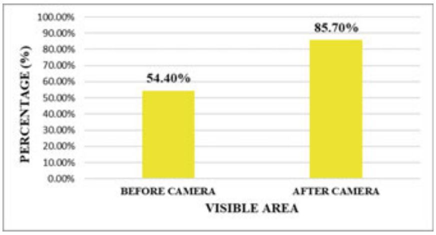
Blind Spot Reduction in 95th Percentile A3 Segment



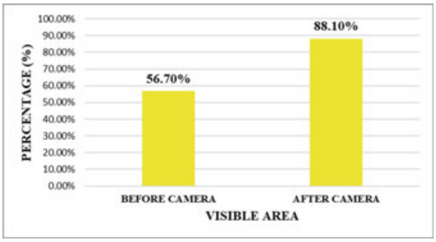
Blind Spot Reduction in 5th A2 Segment



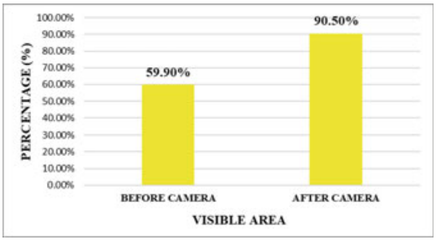
Blind Spot Reduction in 95th A2 Segment



Blind Spot Reduction in 5th A2 Segment



Blind Spot Reduction in 95th A2 Segment



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Chapter 27
Identifying Ergonomic Risk Factors in a Drilling Task: A Literature Review

Umair Arif and Saman Ahmad

1 Introduction

WMSDs result in considerable human suffering and major economic burden to the worker as well as the employer. The economic implications of WMSDs include direct costs like compensation to victims, medical care, etc. and indirect costs in the form of loss of production, replacement costs and absenteeism to name a few. It is believed that WMSDs develop with time, if a person's working environment is not healthy. Work-related musculoskeletal disorders are common in industries (Joshi et al. 2001; Gangopadhyay et al. 2007; Brooks 2006). Some task factors that affect workers are awkward working posture, use of excessive force, repetitive movements, local contact stresses and poor workplace design. Repetitive work exertions are known to increase discomfort in the necks (Hagberg 1981). Uncomfortable shoulder postures and wrist flexion angles result in increased muscle activity and discomfort rating (Brookham et al. 2010; Kim and Fernandez 1993). Worker characteristics like age, gender and experience also have a bearing on fatigue, which may eventually result in the development of WMSD in the long run. Inexperienced workers in industry tend to feel more fatigued in the deltoid, trapezius (upper portion), and supraspinatus muscles whereas an experienced worker felt fatigued in supraspinatus muscles only (Kadefors and Herberts 2014). Heavy static load for older people results in fatigue of supraspinatus muscle due to chronic tendinitis of the rotator cuff (Herberts and Kadefors 1976).

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Almost all industries involve the use of power tools, particularly hand-held types. Hand drill is one such example which finds high utility among carpenters and industrial workers. The ergonomics issues and physical exposures associated with a hand drill are awkward posture, heavy load from drilling effort, weight of the drilling machine, and vibration. The use of un-ergonomically designed hand held tools have been known to cause WMSDs in industries (Chaffin et al. 2006). Hand arm vibration while using a drill may result in hand arm vibration syndrome (Singh and Khan 2014). Load applied during drilling could cause fatigue in elbow, shoulder, and lower back.

The paper therefore attempts to identify the factors that may have a bearing on workers performance and fatigue in a drilling task on the basis of a review of literature. It highlights the major areas of concern and recommends practical methods of addressing them.

2 Methodology

A systematic analysis of literature, related to drilling task, was carried out. Only peer-reviewed English language journal papers were considered. All major journals were searched for studies. A study was included if it met the following inclusion criteria.

(1) It explored the role of wrist and shoulder flexion angle, age, gender, level of adjustability, tool vibration, drilling speed, work/ rest cycle on human subjects performing a drilling task.
(2) It explored models for predicating posture and fatigue of human subjects during a drilling task.
(3) It explored the role of support systems like ladder, platform, press, exoskeleton or modified drilling methods on human subjects for a drilling task.
(4) It explored the effect of drilling in virtual reality/ real environment on human subjects.

A total of 36 studies were identified that addressed ergonomic factors related to drilling task. These studies were later analysed. The study has been divided into two sections as shown in Fig. 1.

3 Individual and Experimental Risk Factors-Based Studies for Designing a Drilling Task

Studies related to working posture such as wrist and shoulder flexion angles, age and gender of workers, level of adjustability and task parameters such as tool vibration, drilling speed and work/rest cycle are beneficial for ergonomic design of an industrial task.

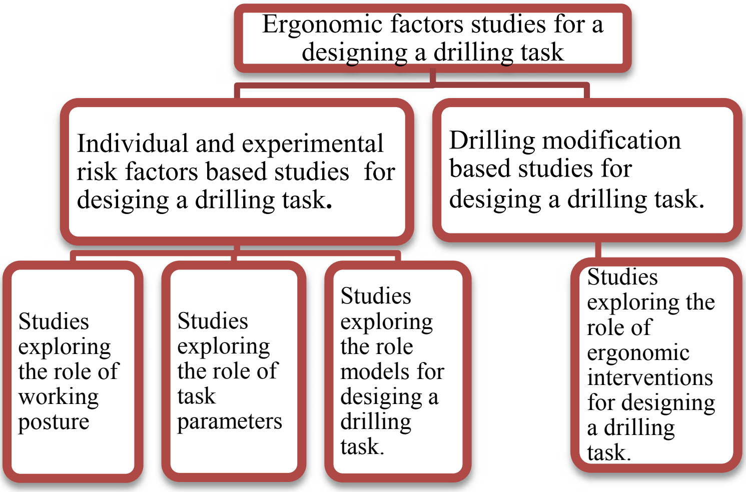

Fig. 1 Classification of studies in sections

A. *Working postures*

Studies on the effect of wrist flexion angle and force applied on maximum acceptable frequency (MAF) in drilling led to the conclusion that the neutral wrist flexion angle is the best for drilling (Kim and Fernandez 1993; Marley and Fernandez 2014). Kim et al. (1993) showed that maximum acceptable frequency reduced significantly with the increase in wrist flexion angle and drilling force. Muscular activity and perceived discomfort ratings were significantly higher with larger wrist angles. Marley et al. recommended that wrist deviation from the neutral position be restricted to a maximum of 1/3rd of flexion (25°) and 2/3rd of ulnar deviation (30°) (Marley and Fernandez 2014). Sasikumar et al. reported that at maximum exertion levels, the index finger produced approximately 27%, middle finger 31%, ring finger 21%, pinky 7% and thumb 14% of the total gripping force (Sasikumar and Lenin 2017). Bjoring et al. showed that the pressure distribution is maximum between thumb and index finger for a simple cylindrical tool handle, in all situations. (Björing et al. 2002) This pressure is directly proportional to the handle size and feed force. The pressure levels reduced with a compressible rubber cover for handles, use of gloves or a supporting handle. However, they were unaffected by vibrations, change in axis of drilling or weight distribution or the width of the handle. Hence a drilling tool handle should be designed to distribute pressure evenly on the hand.

Brookham et al. (2010) concluded that drilling at neutral shoulder elevation and 45^0 internal rotation produced lower activity in the inferior trapezius muscle. However, the activity of middle trapezius decreased non-significantly for 90^0 flexion and deltoid muscle activity continued to increase with flexion angle. Maciukiewicz et al. (2016) showed that middle deltoid, upper trapezius, supraspinatus, and infraspinatus muscles were more active in unilateral tasks. Bilateral task resulted in more EMG activity of the dominant upper trapezius and less EMG activity of supraspinatus muscles and middle deltoid muscles. Hence use of both hands is more beneficial in reducing glenohumeral stability challenges in the drilling task. As compares to standing, muscle activity was lower in a sitting posture. They further concluded that for all overhead drilling tasks, the vertical direction drilling produced less muscle activity than horizontal direction drilling. Anton et al. (2001) reported that performing overhead horizontal drilling tasks close to body helped in reducing shoulder force compared to an extended reach. While the close reach position significantly reduced EMG activity of anterior deltoid, triceps, and shoulder moment, it increased EMG activity of triceps brachii. Sasikumar et al. (2017) showed that bent forearm offered less force than the straight forearm and above shoulder forearm. Stress values in hand were the highest for the extended forearm and elbow at 180° followed by drilling above shoulder level height. Mean time to drill was lowest for drilling above shoulder level. According to Alabdulkarim et al. (2017) adjustable task positions lead to improved productivity, quality and reduced ergonomic risks. Further, Mehta et al. (2010) arrived at the conclusion that muscle activation and performance during the drilling task were significantly affected by age, fatigue, and gender. Fatigue decreased performance of a drilling task and was found to change with factors such as age and gender. Nussbaum et al. (2001) opined that females developed fatigue less rapidly than males when performing drilling at same percentages of muscle capacity.

B. *Task parameters*

The effect of drill tool vibration on workers' physiological parameters is less explored (Widia 2008). Muzammil et al. (1987) reported a significant effect of vibration on human performance measures. Widia and Md Dawal (2010) found that the muscle most affected by vibration was the extensor Carpi radials muscle of right hand. Widia and Dawal (2011) further showed that electric drill produces more vibrations and muscle activity than a bench drill. Also, as the level of vibrations increase, the muscular activity increases, and grip strength decreases. Singh and Khan (2012) concluded that handle position had a significant effect on both discomfort rating ($p < 0.001$) and MVC grip strength ($p < 0.001$). They showed that handle placed at centre of tool gave best results. Further, an increase in feed force resulted in a reduction of the vibration levels of machine, signifying that more vibrations were absorbed by the human hand/arm at higher applied forces. Further Singh and Khan (2014) concluded that the handle covers significantly reduced vibration spreading in the Z direction. Handle covered with rubber sheets and Rexene absorbed most vibrations and allowed very few vibrations to hand in the z-direction. Handle covered with cotton kept between jeans cloth was second-most effective in absorbing vibrations. Handles covered with a sponge plus velvet and jute plus cotton transmitted the same vibrations to hand. Vibrations transmitted to hand were largest in the case of the uncovered handle.

Jagvir et al. concluded that feed force had a significant effect on discomfort score and productivity (Singh and Khan2012; Kim and Fernandez 1993). Higher feed force lead to more discomfort and productivity of workers (Alabdulkarim et al. 2017; Singh and Khan 2012). On the other hand, Muzammil et al. reported that feed force had no significant effect on heart rate and blood pressure of subjects performing a drilling task (Muzammil et al. 1987). Masood et al. (Ashraf et al. 2013) concluded that drill speed had a significant effect on the material removal rate and discomfort score. An increase in drill speeds resulted in decreased discomfort score for a smaller time period. Nussbaum et al. (2001) concluded that the duty cycle (work/rest) is an important parameter for designing and analysing any work task. It has been recommended that a duty cycles greater than 50% for a two-hour period of overhead work, and tool masses greater than 1.25 kg should be avoided (Sood et al. 2017).

C. *Models*

Mathematical model that help in predicting postures, muscle fatigue can be important in ergonomic designing of an industrial task. Ma et al. (2009) proposed a mathematical model for posture prediction and analysis based on multiple-objective optimization methods (MOO). Their application case was drilling holes on the perimeter of a virtual aircraft. The drilling force applied was around 49 N. Generally, a hole is drilled in 30 s. The models lacked approach to muscle level and fast operations.

Ma et al. (2010) suggested different muscle fatigue and recovery model. It included joint level fatigue evaluation and work-rest schedule in manual handling jobs. Their job consists of drilling holes around a section which was a junction of 2 fuselage section with rivets. They concluded that as distance increases elbow becomes more comfortable as it reaches its resting position, and the shoulder becomes more uncomfortable as it moves away from its resting position. The optimal distance is found to be 0.53 m and optimum flexion angle for shoulder and elbow is 22° and 98° respectively for the horizontal drilling task.

Ma et al. (2013) conducted a study to determine the rate of local muscle fatigue in the shoulder joint based on the model developed above. Exponential function best fitted the time course of strength decline. Regression analysis showed a good correspondence (R2. 0:8) for 35 out of 40 subjects. Significant inconsistency in the fatigue rate was found among subjects.

D. *Summary*

The following points need to be kept in mind while designing a drilling task.

(i) Task should be designed such that wrist flexion angle is in a neutral position.

(ii) Tool handle should be designed to avoid pressure in between thumb and index finger muscle region. Drilling tool should be used with a supporting handle, preferably placed in the middle. Wearing gloves or covering tool handles with compressible rubber and use of larger handles are encouraged.

(iii) Overhead drilling in the vertical direction should be done close to the body with medium arm extension in an upward direction. Forearm in bending position as well as use of both hands should be preferred.

(iv) Horizontal drilling should be done at neutral shoulder elevation and 450 internal rotation, or 600 shoulders flexion and 450 internal rotation. Freedom to adjust while drilling should be promoted.

(v) Workers age and gender must be appropriately selected keeping in mind that they also affect muscle fatigue for drilling task.

(vi) Use of tools with lower levels of vibration should be encouraged as increase in vibrations causes increase in the muscular activity, and decrease in grip strength

(vii) Higher drill speed and rest between drilling work should be encouraged.

Table 1 shows sample size, direction of drilling, independent measures and dependent measures used in these studies. Further studies on the role of wrist flexion angle for drilling task are missing. Moreover the wrist flexion study of Marley and Fernandez (2014) did not consider larger working duration, females population and the role of load. Many studies such as (Anton et al. 2001; Sood et al. 2017; Yoon 2012; Phelan and O'Sullivan 2014) and (Singh and Khan 2012) lacked larger samples size, experienced subjects and longer work duration. Studies such as (Maciukiewicz et al. 2016) and (Sood et al. 2017) lacked the effect of different height on drilling task. The study of Maciukiewicz et al. (2016), Alabdulkarim et al. (2017), Marley and Fernandez (2014) and Sood et al. (2017) did not considered the effect of tool vibration and experience of workers in their study. The study of Singh and Khan (2012) and Anton at el. (2001) lacked drilling on different materials like wood, concrete, brick, etc. The study of Anton at el. (2001) did not take into consideration dynamic or static 3D biodynamic. Alabdulkarim et al. (2017) did not consider individual and psychosocial/organizational risk factors and were unable to give any relationship between adjustability and performance/risk.

(2) Slightly Harder Way: Using a scanner as above, save.

Table 1 Key factors from the studies related to individual and experimental risk factors for a drilling task

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
15 healthy female workers	Horizontal drilling	Force applied (2.73, 5.45, 8.18, and 10.91 kg), Wrist flexion angle (0, 10, 20^0)	Muscle EMG, heart rate, blood pressure, and perceived discomfort ratings	Kim and Fernandez (1993)
12 healthy female workers	Horizontal drilling	Wrist posture (0, 1/3 and 2/3 of wrist flexion)	Heart rate, EMG of the anterior deltoid and forearm flexors, blood pressure (diastolic, systolic), as well as subjects discomfort ratings	Marley and Fernandez (2014)
12 healthy female workers	Horizontal drilling	Drilling time (1-min and 3-min) wrist position (neutral, 2/3 maximum in both flexion and ulnar deviation, the combined 2/3 maximum flexion and ulnar deviation.)	Heart rate, EMG activity of the anterior deltoid muscles, and forearm flexors muscle, Blood pressure	Marley and Fernandez (2014)
6 Male and 6 Female workers	Horizontal drilling	Feed force (40, 80,120 N), vibration level, working direction, weight distribution, glove, the use of an additional handle, four handles covered with different hardness rubber and impact drills with 3 different handles	Hand pressure at 16 points	Björing et al. (2002)

(continued)

Table 1 (continued)

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
20, 12 male and 8 females	Overhead vertical direction	Far, middle and close reach for drilling posture, Standing on an upper step, subordinate step of a ladder	EMG activity (Root mean square amplitude) of biceps brachii, anterior deltoid, and triceps muscles	Anton et al. (2001)
5 males and 5 females subjects	Horizontal direction	Handgrip at 30% MVC, Forward push force (13 + −2 N) Shoulder flexion angle of the right arm (0^0, 60^0, 70^0, 80^0, and 90^0)	EMG activity of descending, middle and ascending trapezius of the right hand, Middle, posterior and anterior deltoid and, pectoralis major (clavicular insertion), infraspinatus and latissimus dorsi	Brookham et al. (2010)
22 right-handed male subjects	Horizontal and vertical direction	12 unilateral and 12 bilateral overhead drilling tasks, Direction (horizontal, vertical), Place of force application (15 cm, 30 cm and 45 cm from the body), Body posture (standing or seated.)	EMG activity of middle deltoid, anterior deltoid, ascending trapezius, infraspinatus, supraspinatus, and lumbar erector spinae	Maciukiewicz et al. (2016)
12 (18–35 years), 10 (45–60 years)	Horizontal direction	Shoulder fatigue, age (younger, older), task (low, medium, high levels of difficulty) Gender (male, female)	Muscle activity of the anterior deltoid coactivity indices of the upper and lower arm, task performance, and perceived discomfort ratings	Mehta and Agnew (2010)

(continued)

Table 1 (continued)

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
17 males, 1 female subjects	The vertical and horizontal direction	Workstation adjustability i.e. none adjustability (squatted, or sat on the floor), some adjustability (using a 2-step stool for reaching higher rug), high adjustability (fuselage could be rotated acc to preference) and Force levels (66.7, 111.2 N)	Quality (imperfect holes) Productivity (finishing time), and Ergonomic risk assessment by RULA and the Strain Index	Alabdulkarim et al. (2017)
30	Vertical direction	1st study feed force (100, 200, and 300 N), vibration levels (0.3, 0.5, and 1 m/s^2) for period of 3 min 2nd study time durations (10, 15, and 20 min) and vibrations levels (0.3, 0.5, and 1 m/s^2) with a feed force of 200 N	Pulse and blood pressure of the operators	Muzammil et al. (1987)
–	Vertical direction	Hand- held vibration	Physiological parameters	Widia 2008
3 males, 4 females	Vertical direction	Exposure time (5, 15 min)	% MVC of bicep brachii, extensor carpi radialis, and Trapezius p descendens and grip strength	Widia and Md Dawal (2010)
9 male and 9 females	Vertical direction	Exposure time (5, 15 min) for bench drill and an electric drill	% MVC of bicep brachii, extensor carpi radialis, and Trapezius p descendens and grip strength	Widia and Dawal (2011)

(continued)

Table 1 (continued)

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
9 right-handed males	Horizontal direction	3 different main handle positions i) 3 cm above the spindle axis, 3 cm below the spindle axis and middle position, three feed forces (40 N, 60 N, and 80 N	Perceived discomfort levels and MVC grip strength	Singh and Khan (2012)
5 males	Horizontal direction	5 different wooden handles, covered with sponge and velvet, jute, cotton, rubber sheets, and Rexene, cotton sandwiched between jeans cloth respectively and one handle uncoated	RMS values of vibrations at the surface of the handle and wrist of the subject	Singh and Khan (2014)
12 left-handed subjects	Horizontal direction	3 hand arm postures i.e. Extended forearm with the elbow at 180°, Bent forearm with the elbow at 90°, forearm above shoulder level)	5 force readings for each finger of hand from the sensors	Sasikumar and Lenin (2017)
7 males	Vertical direction	Drill speed (300 and 700 rpm) and 3 levels of time duration (5, 10, 15 min)	Discomfort score and material removal rate (MRR)	Masood et.al. (Ashraf et al. 2013)
8 males and 8 females	Overhead vertical direction	Arm reach (50% and 75%) and duty cycle (20/40 and 40/20 in min ratio denote work/rest) and hand orientation of a tapping task	MVEs of trapezius (TRAP), middle deltoid (MD), anterior deltoid (AD), and infraspinatus and subjective discomfort charts	Nussbaum et al. (2001)

(continued)

Table 1 (continued)

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
24 males and 12 females	Vertical direction	Duty cycle (33%,50%,67%) and tool mass (0.5,1.25,2 kg)	Perceived Discomfort rating	Sood et al. (2017)
–	–	Model for posture prediction and analysis method based on multiple-objective optimization methods (MOO)	Fatigue in the right arm	Liang Ma et al. (2009)
–	–	2 work cycle i) 30-s drilling and 30-s recovery, ii) 30-s drilling, and 60-s recovery	The discomfort index and stress index	Liang Ma et al. (2010)
40 males		1 MVC and 9 fatiguing measures (15, 30, 45 60, 75, 90, 120, 150, 180 s) with a 25 N applied drilling force	Maximum muscle strengths over time and subject-specific fatigue rates of shoulder joint moment strength were measured	Liang Ma et al. (2013)

4 Drilling Modification Based Studies for Designing a Drilling Task

Drilling modification and ergonomic interventions help to reduce risk and are beneficial for ergonomic design of an industrial task.

Yoon (2012) concluded that the best posture for drilling was supine (compared to lying on the floor, standing, and standing on a ladder). They observed an increase in neck discomfort rating, when the posture changed from supine to standing and then ladder respectively. Phelan and O'Sullivan (2014) showed a ladder to be more a suitable option for shoulder muscles activity and task performance as compared to mobile elevated working platforms. However, the result should be taken in the context of the short time duration (5-min) and small sample size (14 people). Transformed average EMG activity of the Upper Trapezius muscle was higher than anterior deltoid muscle on both platforms. Anton et al. (2001) showed that drilling closer to the body by stepping higher on the ladder is more beneficial for anterior deltoid and triceps.

Venkata (2006) found an overhead support system, consisting of a belt and a support rod arrangement, effective in reducing muscular load. Rashedi et al. 2014 observed that using a mechanical arm and an exoskeletal vest as a wearable assistive device (WADE) for overhead work decreased upper extremity RPDs by ∼50% for heavier payloads. Reid et al. (2017) showed that use of exoskeletons can be the beneficial of labor-intensive tasks. Alabdulkarim and Nussbaum (2018) concluded that shoulder support exoskeleton design, decreased shoulder muscle activity but increased loading on the lower back. However, drill quality was found to be low when the tool was attached to a mechanical arm. A full-body exoskeleton resulted in the least MAF and upper-body devices resulted in most MAF for females. Mubbasher et al. (Khan and Muzammil 2018) developed a modified bench drilling machine (MDM) and showed that MDM increased the MRR and endurance time while decreasing the drilling load substantially.

Rempel et al. (2007) developed two prototype support systems namely the Foot Lever Drill Press and the Inverted Drill Press and termed them as Generation 1 support systems. They tested these prototypes by drilling an equivalent number of holes into the concrete or metal ceiling. 53% of the subjects preferred their usual method, 27% preferring the Inverted drill Press, and 18% preferred the Foot Lever Drill Press. However, both devices were found to be less fatiguing than the usual method. In 2009 Rempel et al. (2009) published the results for generation 1 devices. Generation 2 inverted drill press was made based on the feedback of subjects and was tested using the same method as above. All subjects rated the Generation 2 devices as more comfortable with 93% preferring the intervention devices over their usual method (Rempel et al. 2010a). Generation 3 inverted drill press was developed based on the feedback of 13 construction workers. The final design of the device provided much less arm fatigue and the same productivity as the usual method for overhead drilling. Rempel et al. (2010b) used the above 3 generation intervention devices for overhead drilling. Use of intervention devices resulted in lower shoulder fatigue and shoulder flexion angle as compared to the usual method. Generation 3 inverted drill press received the best usability ratings. Chueh and Ro (2009) further incorporated several design changes such as mirror/camera with display in generation 3 inverted drill press and termed it generation 4 device. Results showed that interventions provided improved usability, reduced fatigue, and improved neck posture. Table 2 further shows sample size, direction of drilling, independent measures, dependent measures and major findings used in these studies.

The relationship between virtual reality environment and real environment is important for an ergonomic design of an industry. Conducting experiments in established Virtual Reality (VE) environments is much easier, if ergonomic measures for both come out to be similar. This would reduce time, money and

Table 2 Key factors from the studies related to ergonomic interventions for a drilling task

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
10 subjects	Vertical direction	Drilling 20 holes on the ceiling using three different postures (lying on the floor, standing, and standing on a ladder)	Perceived fatigue in neck, shoulder, elbow, hand, and overall body	Yoon (2012)
19 experienced electricians	Horizontal direction	2 platforms (ladder and MEWPS) and 3 tasks (drilling, cabling, and assembly)	Discomfort, EMG amplitude and task performance, (50th and 90th percentile MVE) for upper trapezius and anterior deltoid	Phelan and O'Sullivan (2014)
14 subjects	Horizontal direction	2 platforms (ladder and MEWPS) and 3 tasks (drilling, cabling, and assembly)	Discomfort, EMG amplitude and task performance, (50th and 90th percentile MVE) for upper trapezius and anterior deltoid	Phelan and O'Sullivan (2014)
5 males subjects	Horizontal direction	Drilling in near reach, middle reach, and far reach positions with and without support	RMS value is taken from the bicep, dominant side of anterior deltoid, and trapezius muscles as well as a subjective rating scale	Bharat Kumar Bhogaraju Bhallam Venkata (Venkata 2006)
12 subjects	Vertical overhead drilling	Payloads (1.1, 3.4, and 8.1 kg) and with/without the WADE for 10 min	Discomfort Rating and EMG for the anterior and middle deltoid (AD and MD), triceps brachii (TB), and iliocostalis lumborum pars lumborum (ILL)	Rashedi et al. (2014)

(continued)

Table 2 (continued)

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
30 subjects	Vertical direction	Time Duration (3, 6 and 9 min), postures (standing and sitting)	Perceived discomfort score (PDS) and metal removal rate (MRR). Drilling load and endurance time	Mubbasher et al. [46]
14 subjects	Vertical direction	Drilling the equivalent number of holes into the concrete or metal ceiling using foot level drill press and inverted drill press	Questions based on set-up time, moving to the next hole, productivity, or overall rank	Rempel et al. (2007) Rempel et al. (2009)
23 subjects	Vertical direction	Drilling an equivalent number of holes into the concrete or metal ceiling using a modified inverted drill press	Questions based on set-up time, moving to the next hole, productivity, or overall rank	Rempel et al. (2010a)
16 subjects	Vertical direction	Drilling an equivalent number of holes into the concrete or metal ceiling using all 3 intervention and usual method	Usability, fatigue, and shoulder flexion angle	Rempel et. al. (2010b)
7 subjects	Vertical direction	Drilling by the usual method, the 4th Generation Inverted Drill Press (without a mirror or a camera), the Inverted Drill Press with a mirror (IDPw/M) for overhead drilling, and the Inverted Drill Press with a camera display system (IDPw/C)	Questionnaire on drilling parameters and physical fatigue levels	Chueh and Ro, (2009)
16 subjects	Vertical direction	4 device conditions (3 exoskeletons, 1normal), and 2 tool mass (2, 5 kg). Three exoskeletons used were: upper-body exoskeletons with attached mechanical arms and full-body exoskeletons; and an upper-body exoskeleton providing primarily shoulder support	MAF, perceived discomfort, quality, and EMG reading from middle and anterior deltoids (MD and AD), triceps brachii (TB), and iliocostalis lumborum pars lumborum (ILL)	Alabdulkarim and Nussbaum (2018)

(continued)

Table 2 (continued)

Sample size	Direction of drilling	Independent measures	Dependent measures	Authors
30 subjects	Horizontal direction	2 working postures (sitting and standing), 2 task durations (long and short), and target size (large and small)	Elbow angle, maximum force capacity reduction, task completion time, Body Part Discomfort, and Perceived discomfort rating	Hu et al. (2010)

changes can be made at an early design stage. Hu et al. explored this relationship (Hu et al. 2010) between virtual reality and real environment and concluded that individuals fatigued faster in VE for a drilling task. All dependent measures except elbow angle were significantly higher in virtual environment than in real environment.

Summary

The following points needs to be kept in mind while designing a drilling task.

(i) Use of a ladder should be promoted.
(ii) Use of assistive devices such as exoskeletons, WADE or Modified bench drilling machine should be encouraged.
(iii) The use of interventions such as Inverted drill press with camera display system should be provided if available.

Table 2 shows sample size, direction of drilling, independent measures and dependent measures used in these studies. Many studies (Phelan and O'Sullivan 2014; Venkata 2006) lacked testing of different muscle fatigue. Some studies lacked larger work duration and female and older population (Venkata 2006; Rashedi et al. 2014; Rempel et al. 2010a). The study of Chueh and Ro (2009) lacked faster inverted drill press in approaching the target, inexperienced subjects and larger exposure time. The study of Alabdulkarim and Nussbaum (2018) lacked vibration exposure analysis and various overhead task. The studies of Hu et al. (2010) lacked higher-fidelity VR systems, more than 6 magnetic sensors, more posture angles, VR experienced subjects.

5 Discussion

This paper systematically explains various facets of ergonomics for designing a drilling task as well as the possible ergonomic intervention. It can be concluded from the above studies that virtual reality and model-based studies are more cost effective whereas experiment-based studies are easy to perform. Sasikumar and Lenin (2017) experimentally showed that bent forearm offers less force on shoulder muscles than the straight forearm and above shoulder forearm. Mathematical model of Ma et al. (2010) also supported these results. Ergonomic studies on drilling tasks are

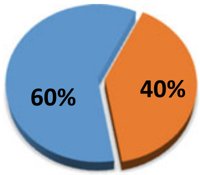

Fig. 2 Studies exploring ergonomic factors for designing a drilling task

relatively few. From the literature analyzed it was found that about 60% researchers have focused on individual and experimental risk factors and 40% have focused on developing intervention devices for making the task of drilling safer and less prone to the development of WMSDs as shown in Fig. 2. It was also found that only four studies explored the role of wrist flexion angle, three explored the role of shoulder flexion angle whereas only one explored the role of age and gender for the ergonomic design of drilling task. Similarly, six studies explored the role of vibration, one explored the role of drilling speed and two explored the role of duty cycle on the drilling task. Only three studies related to models for predicting posture and muscle fatigue were found for a drilling task in the literature analysed. Around 12 studies explored the role of ergonomic intervention for a drilling task. Only one study exploring the role of virtual reality was found.

6 Conclusion and Recommendations for Future Work

After analysing the available literature, one finds that there is a shortage of research on ergonomic design of a drilling task. Sample size of subjects usually varied from 5 to 30. Studies on ergonomic aspects of individuals performing a drilling task such as his/ her wrist flexion angle, shoulder flexion angle, adjustability, age and gender show that neutral wrist position, neutral shoulder elevation and 45^0 internal rotation and bilateral technique provide lower muscle fatigue. Studies covering various ergonomic aspects of drilling tool such as tool vibration, handle size, handle position and coating show that a well-designed tool is one that has low vibrations and good handle covering. A 50–50 duty-work cycle is recommended. Ergonomic interventions (like exoskeleton, inverted drill press) also reduce muscle load and improve endurance time and productivity.

- More studies exploring the role of wrist flexion angle for a drilling task can be done.
- Further ergonomics studies are required for designing an overhead drilling task in horizontal direction.

- Drilling speed, tool mass and their effect on human health and performance is another area where more studies are required.
- More studies relating to mathematical models than can predict the subject's endurance time and productivity precisely need to be undertaken.
- Further, ergonomic studies connecting virtual reality and real environment need to be performed.

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Chapter 28
Impact of Covid-19 Pandemic on Occupational Stress Level Among IT Professionals

Stuti Gupta

1 Introduction

For many of us, COVID-19 pandemic has been one of the most major, and perhaps the most stressful, experience of our lives. Our mobility has become severely restricted and some of us have already lost track of time, wondering which day of the week it is (Ketchell 2020). Unlike a fleeting event, Noval coronavirus has unfolded over many months, with no firm end date in sight. The after effects of the pandemic is presumed to be long lasting and will certainly impact the workforce, regardless of role, industry or location. Economic disruption caused by the pandemic has affected almost every corner of the word (William 2020). All the major industries are adversely affected by the pandemic and growth rate of most of the countries has declined in recent time. Corporate word is in a transition state and both employers as well as employees are trying to adapt as per the new constraints set by the pandemic. The current scenario has imposed work from home across those sectors where remote working is possible. IT organizations have emerged as one of the most critical sectors which provided the required support for other industries to grow and cope with the situation. The pandemic situation has affected the IT organizations in all three dimensions i.e. ***complexity, uncertainty and opportunities*** (Pennington 2020).

Workplace transformation due to pandemic situation, forced majority of the IT professionals to work from home. Almost every organization is compelled to explore this option in view of the Covid-19 pandemic. Government of India is also thinking about '***Flexi Labour Laws***' and suitability of WFH as a long term option to ensure future readiness against such scenario(s) (Sharma 2020). Some of the IT organizations are promoting work from home practices to increase the productivity and save cost. All these initiatives by public/private sector players imply that WFH is here to stay and in recent future employers will be promoting their employees to work

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from home. Employee and employer quickly figured out how to work from home and even when the pandemic subsides, option of work from home is expected to remain available for IT professionals, and that will force companies, even those that were not the biggest proponents of having a virtual workforce, to become more flexible.

Occupational Stress among IT professionals has always been a major concern. The stressors associated with physical, psychological and environmental parameters have become quite significant due to the pandemic situation. Along with the traditional stressors, career instability and fear of losing job have emerged as some of the key concern for the IT professionals in recent times. The transition in work place environment has forced the individuals to put extra efforts to learn new skills in order to adapt and survive the crisis situation. The changed working environment due to Covid-19 pandemic has a major impact on work and family culture of the employees as well. Work from home, social distancing, online education and virtual meetings become the "New Normal" for IT professionals in recent times (Zeidner 2020). This research paper is based on the study conducted to assess the impact of pandemic on occupational stress level among working IT professionals.

2 Related Study

Occupational stress is considered to be one of the most common health hazards currently being faced by millions of IT professionals in this era. Most of the workers experience work related stress at some point of time in their career, as stressful elements are associated with almost every type of work (Charpe and Kaushik 2008). Researches indicate that increase in work pressure, unrealistic targets, impractical deadlines, excessive job demands, role conflicts, poor management, job insecurity, poor career prospects, and lack of communication among workers are most common stressors in IT organizations.

"**Charpe and Gupta (**2019)" developed *Occupational Stress Inventory (OSI),* which act as a tool for measuring the level of occupational stress experienced by Visual Display Terminal (VDT) operators (Charpe and Gupta 2019). The existing work related to the occupational stress has been referred and the prime stressors were reviewed and divided into three categories i.e. physical, psychological and environmental parameters. The study focused on new constraints emerged due to pandemic situations and related aspects of occupational stress arising due to work pressure and other physical, psychological, social, or organizational factors responsible for stress experienced by IT professionals.

Physical parameters: Occupational Stress Inventory (OSI) consist of the items related to the symptoms of pain and discomfort arising due to the working conditions and static nature of work. Neck and shoulder pain, headaches, back pain, Computer Vision Syndrome (CVS), Carpal Tunnel Syndrome (CTS) and lower body pain were identified as most common physical problems associated with IT work (Louis 2014; Dewangan and Singh 2014). Work from home scenario has worsen the impact of these associated physical parameters. These factors are covered and evaluated through their inclusion in the inventory in the form of: posture, pain, and physiological discomfort.

Psychological parameters: Inventory consists of the items related to psychological stress originating from the work conditions at the workplace. Pandemic situation has not only imposed the new social distancing rules, it has also limited the boundaries of social life of an individual. Isolation, lack of communication and monotonous nature of work are causing lots of problem which eventually result in increased level of stress and other related problems (Eastwood et al. 2012). The points related to psychological dimension were re-evaluated in view of the changed through their inclusion in the inventory in the form of: boredom and monotony due to the nature of work, very limited job control, improper rest schedules, low job clarity, low social support, lack of communication, unrealistic demands and deadlines by management, interpersonal relationship with subordinates, colleagues and authorities.

Environmental parameters: Inventory also comprising of the items about the environmental conditions of the workplace. There has been a dramatic transition in the workplace due to work from scenario and majority of the IT professionals have to adapt as per new working conditions. Lack of ideal and dedicated space for work are some of the new challenges which has recently emerged as key stressors. The various aspects of environmental parameters include workplace layout design, furniture design which includes chair, desk, backrest, armrest, footrest and seat depth, width and height, compatibility of pieces with each other—mouse, keyboard, monitor, document holder, indoor climate-glare, light, flicker, hot/cool environment, dryness etc., (Juul and Jensen 2005; Gupta 2016).

The credibility of the Occupational Stress Inventory (OSI) was rated between high to very high by the experts, which signifies it to be a valid instrument covering all the necessary constructs of occupational stress, making it effective in measuring occupational stress levels in IT professionals. The reliability estimate calculation, done by Split Halves (r = 0.83) and Test Retest (0.92) methods, proved the Occupational Stress Inventory (OSI) to be reliable, both in terms of internal consistency and consistency in repeated administration.

OSI is considered to be an effective measuring instrument for occupational stress levels in any IT organization that can act as an aid to identify whether the workplace environment needs any revision in terms of its suitability for the workers. It could be helpful in assessing the stress level for each worker in the organization and taking appropriate counter measures.

3 Materials and Methods

A. ***Locale of the study***

The study was conducted in Lucknow city (Uttar Pradesh) in selected IT companies.

B. ***Sample selection and sample size***

The sample consisted of 100 IT professionals (50 male and 50 female) under the age range of 25–40 years, who have been in the same work sector since last five years. The background information of the subjects was gathered regarding age, work experience, vision acuity and working technique.

C. ***Tools***

Occupational Stress Inventory (OSI) developed by "Charpe and Gupta (2019)" was used a measuring instrument to identify the level of occupational stress among IT professionals. Occupational Stress Inventory comprised of 50 statements.

As a part of research work carried out to develop the OSI for assessment of Occupational Stress among VDT workers, responses of 1000 IT professionals (500 males and 500 females) were collected against each of the 50 items mentioned in Occupational Stress Inventory. The respondents were required to give their responses in terms of their own degree of agreement or disagreement towards the items. Responses were quantified on the basis of Likert scaling technique and assigned numeral values for the responses ranging from 1 to 5. As there were 50 items in the OSI to be responded on a 5-point scale (1, 2, 3, 4 and 5), the raw scores of any respondent could vary from 50 as minimum to 250 as maximum and the corresponding z-scores were calculated for all possible raw scores. The activity was carried out during 2016 i.e. long before pandemic when the situation was considered to be normal in comparison to the ongoing pandemic situation. Previously collected data was used as a reference and for comparing it with new set of data collected during pandemic. Out of these 1000 employees working in different IT companies, 100 employees were chosen (50 males and 50 females) who have been working in the same field since last 5 years. Responses of these 100 employees were obtained in the Occupational Stress Inventory (OSI) against each of the 50 items. The process of collecting data with the inventory was repeated from same respondents during pandemic. The data collected was categorized on the degree of agreement of respondents towards each item in Occupational Stress Inventory (OSI). Representation of the collected data in analytical form was done to perform data analysis. The response sets were tabulated, and data was statistically analysed.

4 Result

The raw scores of the inventory could vary between 50 and 250. Corresponding z-scores were calculated for every single raw score to provide a basis for the interpretation for the scores obtained by the respondents in any VDT work setup. It was found that for the raw scores of the range 50 to 250, the corresponding z-scores vary between −1.72 and +1.72. Table below signifies the various levels of occupational stress based on raw scores against Occupational Stress Inventory (OSI) (Table 1).

The raw scores of 100 respondents were calculated in both scenario i.e. before pandemic (X) and during pandemic situation (Y). The level of occupational stress

Table 1 z-score norms for interpretation of levels of occupational stress

Occupational stress level	Raw scores	z-scores	Stress severity
A	50–90	1.72 to 1.03	Negligible
B	91–130	1.02 to 0.34	Low
C	131–170	0.33 to +0.34	Mild
D	171–210	+0.35 to +1.03	High
E	211–250	+1.04 to +1.72	Severe

Table 2 Frequency distribution of respondents on the scores obtained

Occupational stress severity	Raw scores	X (2016)	Y (2020)
Negligible	50–90	1	0
Low	91–130	6	4
Mild	131–170	21	8
High	171–210	41	51
Severe	211–250	31	37

N = 100

experienced by 100 respondents along with frequency distribution for both the scenario X and Y is tabulated below (Tables 2, 3, 4 and Figs. 1, 2).

Table 3 Frequency distribution of Male/Female respondents on the scores obtained

Occupational stress severity	X1 Males (2016)	X2 Females (2016)	Y1 Males (2020)	Y2 Females (2020)
Negligible	0	1	0	0
Low	2	4	3	1
Mild	13	8	6	2
High	18	23	25	26
Severe	17	14	16	21

N = 50

Table 4 Statistical summary of raw scores

Scenario	N	Mean	Standard deviation
X (2016)	100	192.39	42.45
Y (2020)	100	211.73	30.89
X1 (Male)	50	207	44.55
X2 (Female)	50	205.96	44.73
Y1 (Male)	50	214	43.27
Y2 (Female)	50	225.36	41.12

Fig. 1 Frequency distribution of respondents on the scores obtained

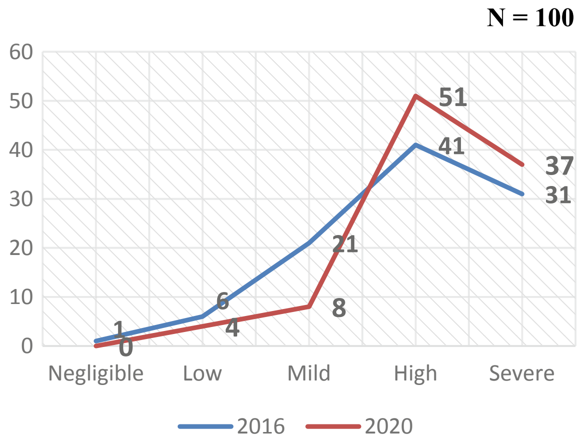
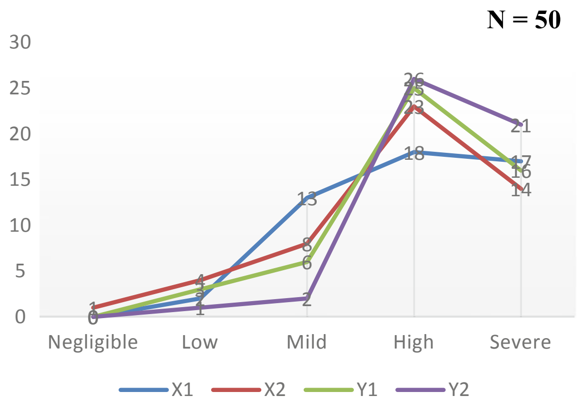


Fig. 2 Frequency distribution of Male/Female respondents on the scores obtained



The above mentioned table reveal that average raw score (Mean) for the 100 respondents has risen from 192.39 (z-score +0.71.36) in 2016 (X) to 211.73 (z-score +1.05) during pandemic (Y). This signifies that there has been overall rise in the level of Occupational Stress on IT professionals from “High” to “Severe” level due to the major workplace transition.

The average raw score of 50 male workers during 2016 (X1) was calculated as 207 (z-score +0.962) and has increased to 214 (z-score +1.081) during pandemic situation in 2020 (Y1). Similarly average raw score of 50 female workers was calculated as 205.96 (z-score +0.9443) during the survey of 2016 (X2) has substantially increased to 225.36 (z-score +1.2741) after the enforcement of work from home practices in IT organizations during 2020 (Y2).

A z-score of the range +1.04 to +1.72 has been categorized as SEVERE and considered most critical scenario i.e. the occupational stress in the organization is unbearable and alarming. The management needs to provide opportunities for social interaction among workers and define work schedules that are compatible with demands and responsibilities of workers outside the job. Along with the stress management programs, workplace discrimination based on race, gender, national origin, religion or language is a major challenge that need to be addressed by the organization to achieve the appropriate stress level. The management needs to define the roles and responsibilities of the workers and make sure that the workload is in line with worker's capabilities and resources. Besides that, workers need to be encouraged to maintain a work-life balance.

The result shows that the Occupational Stress Level among female workers has significantly increased in recent times due to the dramatic change in work place environment. Work from home has not only increased the office work pressure on female employees but it has become difficult for them to maintain work-life balance while staying at home. Covid-19 pandemic has already increased the pressure of additional household duties especially on working women. It was also observed that psychological stressors were more prevalent than environmental and physiological parameters. All these parameters are responsible for a steep rise in the stress level among female workers.

5 Conclusion

COVID-19 pandemic is first a health and humanitarian crisis and then a business challenge. IT work is considered to be tedious, monotonous and demanding as it requires both physical involvement and mental concentration while performing the task. Also, the enhanced ability to communicate and operate has in many ways created an always-on, always-available expectation from employers in IT industries. Study has shown an adverse psychological impact of pandemic on individuals, especially wellbeing of IT professionals. Boredom was identified as one of the major constructs for the occupational stress among the VDT operators which lead to irritation, mental strain and anxiety; which further cause psychological stress on the workers. Lack of job control, long working hours, and high and conflicting work demands were identified as some of the frequently cited causes of occupational stress. The highest level of stress in VDT operators was observed because of high job demands and low job control and work-life balance practices. Microsoft CEO, Satya Nadella, in an interview said that permanently working from home can be damaging for mental health of employees. The study conducted also supports the statement and therefore ***work from home should not be considered as a replacement for traditional work culture*** (Ahmed 2020). Although it may increase the productivity and save cost but it may lead to more sever health condition for the employee in long term. Also female IT professionals need to be extra cautious in the current situation as the pandemic is taking a toll on the emotional well-being of working women. It may be concluded from the study that the transition in workplace due to Covid-19 pandemic is adversely affecting the social life as well as physical and mental health of IT professionals.

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Chapter 29
Impact of Symbology Luminance and Task Complexity on Visual Fatigue in AR Environments

Prerita Kalra and Vinod Karar

1 Introduction

Excessive exertion of the human visual system can lead to visual fatigue. The symptoms of visual fatigue are classified into Internal Symptom Factors (ISF) and External Symptom Factors (ESF) (Sheedy et al. 2003). ESF include irritation, tearing, burning, and dryness in the lower and front part of the eye. They can be caused due to holding the eyelid open, glare, flickering, up gaze, and small font. ISF include aching eye, strain, and head ache behind the eyes. They can be caused due to mixed astigmatism conditions and close viewing distances.

The AR technology augments the real world environment by means of computer generated graphics. It is being used across a number of domains such as aerospace and transportation (Regenbrecht et al. 2005), logistics (Schwerdtfeger et al. 2009), military (Livingston et al. 2011), assembly and maintenance (Webel et al. 2013), healthcare (Barsom et al. 2016), and gaming (Itzstein et al. 2017).

The human eye can only bear a certain level of light (Kalra and Karar 2019). A consistent source of light, when directed at the eye, can lead to visual fatigue. The glare caused by an excessively bright source of light can also lead to visual impairment (Diep and Davey 2018). It is thus understandable that the luminance level of the head up display (HUD) symbology can have adverse effects on the human visual system, if not set properly with respect to the ambient light.

Different degrees of visual attention, required while performing tasks of different complexity levels, can also impact the human visual system.

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Prevention is the primary strategy for managing visual fatigue. This requires educating the users to ensure an ergonomic work environment (Coles-Brennan et al. 2019).

The current work investigates the impact of HUD symbology luminance and task complexity on visual fatigue and human performance.

This research paper is organized along the following lines: the methods are given in Sect. 2, the results and discussion are given in Sect. 3, and the conclusion is given in Sect. 4.

2 Methods

2.1 Participants

Twenty participants in the age range of 20–32 (mean age = 25.55) were taken as the subjects. The visual acuity of the participants was tested to be normal or corrected to normal. No idea about the expected results of the experiment was given to the participants.

2.2 Workstation and Surroundings

This study was conducted in a computer lab, completely lit by means of overhead luminaries. The illumination level of the lab was maintained at 250 lx.

18.5-inch LED backlit monitors were used for the study. The typical brightness of the monitors was 200 cd/m^2. The height and position of the chairs with respect to the monitor was kept such that the viewing angle and viewing distance were maintained at recommended values. The center of the monitor was maintained at 15° below the eye level, and the viewing distance was 24 in.

2.3 Experiment Design

A HUD based plane shooting game, with three complexity levels, was developed using Unity for this study. A screenshot of the same is given in Fig. 1. The levels have been designated as Level 1, Level 2, and Level 3 in the subsequent sections. The task complexity was least in Level 1 and highest in Level 3. Each level was of half an hour duration. Each participant was made to participate in two experiments over a period of two days.

The first experiment, conducted on the first day, required the participant to play the least complex level of the game at three different HUD symbology luminance

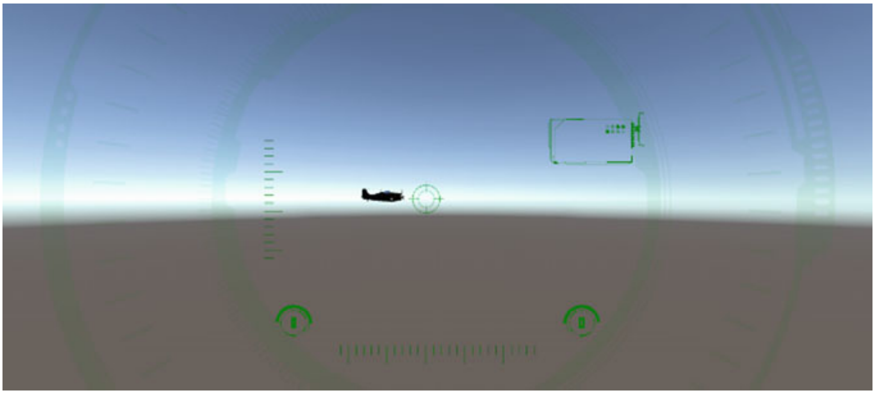

Fig. 1 A screenshot of the HUD based game developed for the experiment

values of 20, 110, and 200 cd/m^2 with an interval of one hour in between each round. These values have been designated as low, medium (med.), and high, respectively, in the subsequent sections.

The second experiment, conducted on the second day, involved playing the three levels of the game with an interval of one hour in between each of the levels. The luminance of the HUD symbology used in the game was set to 110 cd/m^2 for this experiment.

The human performance was measured for every round of the game. The game score was used as a measure for human performance. Hitting an enemy's plane through the HUD added to the score while hitting an ally reduced the score. The frequency at which the visual system perceives a flickering light as continuous is known as the critical flicker fusion frequency (Gautam and Vinay 2020). The visual fatigue level of the participants was evaluated before and after each round of the game using a critical flicker fusion frequency apparatus. The mean of the ascending and descending critical flicker fusion threshold was recorded to measure the level of visual fatigue. The visual fatigue induced in each round was calculated using the difference of visual fatigue level recorded before and after the round.

2.4 Statistical Analysis

IBM® SPSS (Version 23) was used to carry out the statistical analysis. The Friedman Test was used to statistically check whether the performance and visual fatigue levels of the participants were significantly affected by the change in task complexity and HUD symbology luminance or not. The Wilcoxon Signed-Rank Test was used to statistically compare the recorded visual fatigue and performance scores between different pairs of complexity levels and also between different pairs of HUD symbology luminance levels.

Spearman's Rank-Order Correlation was used to determine the correlation between visual fatigue and performance levels recorded across different HUD symbology luminance and task complexity levels. The correlation between task complexity and the dependent variables-visual fatigue and human performance, was also determined using Spearman's Rank-Order Correlation. The correlation was taken to be significant at the 0.01 level.

3 Results and Discussion

3.1 Descriptives

The descriptive statistics-mean, standard deviation and percentile values for the visual fatigue recorded across different HUD symbology luminance levels, are given in Table 1, and those for the human performance recorded across different HUD symbology luminance levels are given in Table 2.

Table 3 gives the descriptive statistics for the visual fatigue recorded across different task complexity levels, while Table 4 gives the descriptive statistics for the human performance recorded across different task complexity levels.

Table 1 Descriptives of visual fatigue recorded across different HUD symbology luminance levels

	N	Mean	Std. deviation	Percentiles		
				25th	50th (Median)	75th
Med	20	3.8000	0.76777	3.0000	4.0000	4.0000
High	20	5.7000	0.80131	5.0000	5.5000	6.0000
Low	20	8.3000	0.73270	8.0000	8.0000	9.0000

Table 2 Descriptives of human performance recorded across different HUD symbology luminance levels

	N	Mean	Std. deviation	Percentiles		
				25th	50th (Median)	75th
Med	20	97.9000	1.71372	97.0000	98.0000	99.0000
High	20	93.2500	2.73140	91.0000	92.5000	95.0000
Low	20	89.7500	3.62557	87.0000	89.0000	92.7500

Table 3 Descriptives of visual fatigue recorded across different task complexity levels

	N	Mean	Std. deviation	Percentiles		
				25th	50th (Median)	75th
Level_1	20	3.8000	0.76777	3.0000	4.0000	4.0000
Level_2	20	11.9500	0.88704	11.0000	12.0000	13.0000
Level_3	20	18.6500	0.87509	18.0000	18.5000	19.0000

Table 4 Descriptives of human performance recorded across different task complexity levels

	N	Mean	Std. deviation	Percentiles		
				25th	50th (Median)	75th
Level_1	20	97.9000	1.71372	97.0000	98.0000	99.0000
Level_2	20	86.8000	3.38106	84.0000	87.0000	89.7500
Level_3	20	77.1000	2.04939	76.0000	76.5000	78.7500

3.2 Friedman Test Analysis

The Friedman Test for the visual fatigue recorded across different HUD symbology luminance levels gave a significance value less than 0.05 ($\chi^2(2) = 39.077$, $p < 0.001$) showing that the difference in the visual fatigue recorded across the three different HUD symbology luminance levels was statistically significant. The Friedman Test statistics for the same are given in Table 5.

The Friedman Test for the human performance recorded across different HUD symbology luminance levels also gave a significance value less than 0.05 ($\chi^2(2) = 37.333$, $p < 0.001$) showing that the difference in the human performance recorded across the three different HUD symbology luminance levels was statistically significant. The Friedman Test statistics for the same are given in Table 6.

The Friedman Test for the visual fatigue recorded across different task complexity levels gave a significance value less than 0.05 ($\chi^2(2) = 40.000$, $p < 0.001$) showing

Table 5 Friedman test statistics for visual fatigue recorded across different HUD symbology luminance levels

N	20
Chi-Square	39.077
df	2
Asymp. Sig	0.000

Table 6 Friedman test statistics for human performance recorded across different HUD symbology luminance levels

N	20
Chi-Square	37.333
df	2
Asymp. Sig	0.000

Table 7 Friedman test statistics for visual fatigue recorded across different task complexity levels

N	20
Chi-Square	40.000
Df	2
Asymp. Sig	0.000

Table 8 Friedman test statistics for human performance recorded across different task complexity levels

N	20
Chi-Square	40.000
Df	2
Asymp. Sig	0.000

that the difference in the visual fatigue recorded across the three different task complexity levels was statistically significant. The Friedman Test statistics for the same are given in Table 7.

The Friedman Test for the human performance recorded across different task complexity levels also gave a significance value less than 0.05 ($\chi^2(2) = 40.000$, $p < 0.001$) showing that the difference in the human performance recorded across the three different task complexity levels was statistically significant. The Friedman Test statistics for the same are given in Table 8.

3.3 Wilcoxon Signed-Rank Test Analysis

The Wilcoxon Signed-Rank Test for the visual fatigue recorded across different HUD symbology levels showed that there is a statistically significant difference between the visual fatigue recorded at high and medium luminance levels of the HUD symbology ($p < 0.001$), the visual fatigue recorded at low and medium luminance levels of the HUD symbology ($p < 0.001$) as well as between the visual fatigue recorded at low and high luminance levels of the HUD symbology ($p < 0.001$). The Wilcoxon Signed-Rank Test statistics for the same are given in Table 9.

The Wilcoxon Signed-Rank Test for the human performance recorded across different HUD symbology levels showed that there is a statistically significant difference between the performance level recorded at high and medium luminance levels of the HUD symbology ($p < 0.001$), the performance level recorded at low and medium luminance

Table 9 Wilcoxon signed-rank test statistics for visual fatigue recorded across different HUD symbology luminance levels

	High—Med	Low—Med	Low—High
Z	−3.810[a]	−3.963[a]	−3.991[a]
Asymp. sig. (2-tailed)	0.000	0.000	0.000

[a]Based on negative ranks

levels of the HUD symbology ($p < 0.001$) as well as between the performance level recorded at low and high luminance levels of the HUD symbology ($p = 0.001$). The Wilcoxon Signed-Rank Test statistics for the same are given in Table 10.

The Wilcoxon Signed-Rank Test for the visual fatigue recorded across different task complexity levels showed that there is a statistically significant difference between the visual fatigue recorded at Level 2 and Level 1 of the game ($p < 0.001$), the visual fatigue recorded at Level 3 and Level 1 of the game ($p < 0.001$) as well as between the visual fatigue recorded at Level 3 and Level 2 of the game ($p < 0.001$). The Wilcoxon Signed-Rank Test statistics for the same are given in Table 11.

The Wilcoxon Signed-Rank Test for the human performance recorded across different task complexity levels showed that there is a statistically significant difference between the performance level recorded at Level 2 and Level 1 of the game ($p < 0.001$), the performance level recorded at Level 3 and Level 1 of the game ($p < 0.001$) as well as between the performance level recorded at Level 3 and Level 2 of the game ($p < 0.001$). The Wilcoxon Signed-Rank Test statistics for the same are given in Table 12.

From Tables 1, 5, and 9, it is evident that the visual fatigue induced is least in case of the HUD symbology luminance being set at a medium level and highest in case of low HUD symbology luminance.

Also, it can be seen from Tables 2, 6, and 10 that the human performance is highest in case of the HUD symbology luminance being set at a medium level and lowest in case of low HUD symbology luminance.

From Tables 3, 7, and 11, it is evident that the visual fatigue induced is least in case of least task complexity and highest in case of highest task complexity.

The human performance is highest in case of least task complexity and lowest in case of highest task complexity as can be seen from Tables 4, 8, and 12.

Table 10 Wilcoxon signed-rank test statistics for human performance recorded across different HUD symbology luminance levels

	High—Med	Low—Med	Low—High
Z	−3.930[a]	−3.924[a]	−3.426[a]
Asymp. sig. (2-tailed)	0.000	0.000	0.001

[a] Based on positive ranks

Table 11 Wilcoxon signed-rank test statistics for visual fatigue recorded across different task complexity levels

	Level_2—Level_1	Level_3—Level_1	Level_3—Level_2
Z	−3.951[a]	−3.962[a]	−3.944[a]
Asymp. sig. (2-tailed)	0.000	0.000	0.000

[a] Based on negative ranks

Table 12 Wilcoxon signed-rank test statistics for human performance recorded across different task complexity levels

	Level_2—Level_1	Level_3—Level_1	Level_3—Level_2
Z	−3.931[a]	−3.930[a]	−3.924[a]
Asymp. sig. (2-tailed)	0.000	0.000	0.000

[a] Based on positive ranks

3.4 Spearman's Rank-Order Correlation

The Spearman's Rank-Order Correlation showed a strong, negative correlation between visual fatigue, and performance levels of the participants recorded across different HUD symbology luminance levels and also across different task complexity levels. The correlation was statistically significant for the visual fatigue and performance levels recorded across different HUD symbology luminance levels ($r_s = -0.777$, $p < 0.001$) and also for the visual fatigue and performance levels recorded across different task complexity levels ($r_s = -0.953$, $p < 0.001$). The results of the Spearman's Rank-Order Correlation for the values recorded across different HUD symbology luminance levels are given in Table 13, and those for the values recorded across different task complexity levels are given in Table 14.

The Spearman's Correlation showed a strong positive correlation between the task complexity level and the level of visual fatigue induced. The correlation was statistically significant ($r_s = 0.949$, $p < 0.001$), and the results for the same are given in Table 15.

The Spearman's Correlation showed a strong negative correlation between the task complexity level and the performance level. The correlation was statistically significant ($r_s = -0.943$, $p < 0.001$) and the results for the same are given in Table 16.

Table 13 Spearman's rank-order correlation between visual fatigue and human performance recorded across different HUD symbology luminance levels

			Visual_fatigue	Human performance
Spearman's rho	Visual_fatigue	Correlation coefficient	1.000	−0.777**
		Sig. (2-tailed)		0.000
		N	60	60
	Human_performance	Correlation coefficient	−0.777**	1.000
		Sig. (2-tailed)	0.000	
		N	60	60

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

Table 14 Spearman's rank-order correlation between visual fatigue and human performance recorded across different task complexity levels

			Visual_fatigue	Human performance
Spearman's rho	Visual_fatigue	Correlation coefficient	1.000	−0.953**
		Sig. (2-tailed)		0.000
		N	60	60
	Human_performance	Correlation coefficient	−0.953**	1.000
		Sig. (2-tailed)	0.000	
		N	60	60

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

Table 15 Spearman's rank-order correlation between task complexity and visual fatigue

			Task_complexity	Visual_fatigue
Spearman's rho	Task_complexity	Correlation coefficient	1.000	0.949**
		Sig. (2-tailed)		0.000
		N	60	60
	Visual_fatigue	Correlation coefficient	0.949**	1.000
		Sig. (2-tailed)	0.000	
		N	60	60

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

Table 16 Spearman's rank-order correlation between task complexity and human performance

			Task complexity	Human performance
Spearman's rho	Task_complexity	Correlation coefficient	1.000	−0.943**
		Sig. (2-tailed)		0.000
		N	60	60
	Human_performance	Correlation coefficient	−0.943**	1.000
		Sig. (2-tailed)	0.000	
		N	60	60

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

4 Conclusion

The effect of HUD symbology luminance and task complexity on visual fatigue and human performance was studied. HUD symbology luminance levels and task complexity levels were found to significantly affect the visual fatigue induced in the participants and their performance levels. Under typical illumination conditions, it was found that setting the HUD symbology luminance at a medium level induced least visual fatigue in the participants and resulted in highest performance levels. It was also found that the highest level of task complexity induced the highest level of visual fatigue and resulted in lowest performance levels. Lower levels of visual fatigue were found to be associated with higher levels of human performance. Increasing the task complexity was found to increase visual fatigue and reduce human performance. It is recommended that the HUD symbology luminance should be set at a medium level when working in AR environments under typical illumination conditions.

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Chapter 30
Influence of Weights for Selected Cognitive Abilities: An Online Approach

M. P. Giridhar and Vinay V. Panicker

1 Introduction

Cognitive research, including psychology, philosophy, linguistics, neuroscience, computer science, and anthropology, may be considered a union of various fields. Cognitive scientists strive to understand the essence of our thought, what is universal and variable about it, and how the variety of situations we encounter reacts to and is influenced by human cognitive mechanisms (Barrett 2020). Cognition is a term that refers to the mental processes involved in learning and understanding. Many aspects of intellectual functions and processes, such as attention, memory, computation, decision making, and learning, are also covered in cognition. Cognitive processes use and produce new information from existing knowledge. There is still controversy about cognitive skills and how it relates to human variations considering each cognitive ability based on future time perspective (Barber et al. 2020).

This study investigates how various cognitive abilities influence the overall cognitive skills of the subjects. Increasingly, cognitive neuroscientists agree that ongoing progress in understanding human cognitive skills would require not only new data acquisition, but also data synthesis and integration through studies and laboratories. Efforts for an increased focus on cognitive skills and their effective way of identification of tasks and experimentation using cognitive atlas contributed to the experimental design of the study (Yarkoni et al. 2010).

Using the Mini-mental State Test (MMSE), which is a generally accepted tool to date, a subject's cognitive status is investigated; however, a few studies doubt its sensitivity. Alternatively, with high sensitivity, Montreal cognitive assessment (MOCA) is considered more effective than MMSE for determining cognitive status. Both of these methods are questionnaire-based, and the accuracy of the data collected

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cannot be accurate as the subjects can manipulate. In this study, scores were given to all tasks done for each subject, and also, feedback was taken for better accuracy in data (Palanisamy et al. 2016). There are several important cognitive functions of the brain.

The mental processes that help us to receive, select, store, transform, develop, and recover information that we have obtained from external stimuli are brain cognitive functions. Cognitive abilities are brain-based abilities required from the easiest to the most complex to carry out any task. They are connected to the processes of how we read, recall, solve and pay attention to problems, etc. (Zhang 2019). The cognitive abilities considered for skill assessment in the present study are as follows:

- Visual perception
- Attention
- Memory
- Motor skills
- Language
- Visual and Spatial processing
- Executive functions and
- Learning.

The above listed eight cognitive abilities are given separate scores based on a pilot study conducted and thus the total score for all the fifteen subjects can be obtained. The weightages of the cognitive abilities are varied and thus the influence of these abilities on the total score of the subject is also considered. These tests can be used for skill allocation in all man–machine environments.

A study emphasizing the importance of negotiating skills in the IT sector was conducted. The negotiation schemata of Finnish and Japanese IT business people are compared in this original empirical study. The research describes negotiation schemes that are used in one or both groups of cultures (Baber and Ojala 2015). This study suggests the importance of the cognitive skills in complex tasks and how their output can be interpreted and applied in workstation design and task allocation.

2 Background

The 'cognitive revolution' was initiated more than half a century ago, with the popular tenet' cognition is computation, through a multidisciplinary endeavor called cognitive science, the study of the mind. A recent study suggests that cognitive science is heavily dominated by psychology (Núñez et al. 2019).

In the cognitive neuroscience of executive function, studies of individual differences have become increasingly important. For example, individual variation in lateral prefrontal cortex function and that of related regions has recently been used to identify contributions to a number of domains of executive control processes, including capacity of working memory, anxiety, reward/motivation, and emotion regulation. However, the roots of such human distinctions remain poorly understood.

For identifying the casual relationships between neural and cognitive processes, recent progress in identifying the genetic and environmental causes of variation in neural traits would be significant for developing a mechanistic understanding of executive function (Braver et al. 2010), in accordance with progress in identifying the casual relationships between neural and cognitive processes.

The emphasis is primarily on the impact of individual skills on cognitive performance. The focus is on skill set as a personality dimension within normal populations rather than within clinically anxious ones, and there is a focus on individual variations in cognitive skills (Eysenck et al. 2007). At any given moment, the visual short-term memory system will retain representations of only three to four objects. The subjects were given tasks considering the above standard.

Considering any task from the easy to complicated, the brain-based abilities are carried out. Rather than with any actual knowledge, they have more to do with the processes of how to understand, remember, solve problems, and pay attention (Evans and Burghardt 2008). Responding to the telephone, for example, requires perception (hearing the ring tone), decision-making (responding or not), motor skills (lifting the receiver), language skills (speaking and understanding language), social skills (interpreting voice tone and appropriate contact with another human being). Unique neural networks endorse cognitive capacities or skill. Memory skills depend mostly on parts of the temporal lobes and parts of the frontal lobes (behind the forehead). Cognition is involved in the major brain functions including visual perception, attention, memory, motor skills, language, visual and spatial processing, executive functions, and learning (Fernandez and Goldberg 2009). A set of tasks depending upon the cognitive abilities required were given to subjects based on the above study which explained a case study of a person receiving a phone.

3 Experimentation/Methods

3.1 Participants

Fifteen subjects between 20 and 31 years of age participated in the study. Subjects were given all the instructions prior to the task. All the subjects had done these tasks in the comfort of their home. The experiment was conducted in a friendly atmosphere to avoid the stress and to obtain maximum output. Each subject performed different tasks respective to the eight scenarios, and equal time were given to all.

3.2 Experiment Procedure and Apparatus

The study was conducted with two laptops where one will be on the instructor's side and the other will be on the subject side. The subject and the instructor are in their

Fig. 1 Virtual view from the instructor's laptop during the task

respective homes, and the internet speed test was conducted before the experiment. A fixed amount of time was given to all the subjects, and one to one interaction was done through an online video calling platform. Eight cognitive abilities of the subjects are conducted with eight different sections. All the instructions for the tasks were illustrated using the screen sharing method as per Fig. 1. Instructor also gives oral instructions, and the scores are noted manually. The tasks were also recorded with the faces of the subjects for more clarity.

3.3 Experimental Design

Eight cognitive abilities are considered in the study. For each cognitive ability a brain teaser or questions based on the section are displayed on the sharing screen of laptop. The subject responds, and the scores are recorded. Mostly brain teasers are given in each section. The individual scores and their weightages are shown in Table 1. The scores added up to a total of 73, where three intervals based on their performance are given.

Table 1 Cognitive abilities and their scores

Cognitive ability	Score
Visual perception	8
Attention	7
Memory	11
Motor skills	2
Language	10
Visual and spatial processing	9
Executive functions	16
Learning	10

4 Results

4.1 Data Analysis

All the fifteen subjects performed the tasks, and their scores out of 73 were noted. The performance of the fifteen subjects based on their cognitive ability scores are listed in Fig. 2. Subject 3 has the highest score and subject 15 has the lowest. The performance rating is done based on the individual scores obtained for each cognitive ability. The average score percentage of the fifteen subjects is 58.81% which is much lesser than that of the highest 75.34%.

The scores are further divided based on their performance into class intervals as per Table 2. Only two of the subjects could achieve the best scores in the study. Nine of the subject's performance was poor and four of them performed good in the experiment. The performance of the subjects showed a variation as per the literature, but the mode of conduct can be challenging for some of the subjects.

In addition, a questionnaire feedback was taken from the subjects to consider the difficulties faced during the transformation from offline mode to online mode during the pandemic period. The pie chart representing that is shown in Fig. 3. The majority (80%) of the subjects considered selected offline mode of experiment. This can be a reason in the decline in performance of the subjects. Only three subjects supported the online mode, but their performance was not very good. A possibility to identify

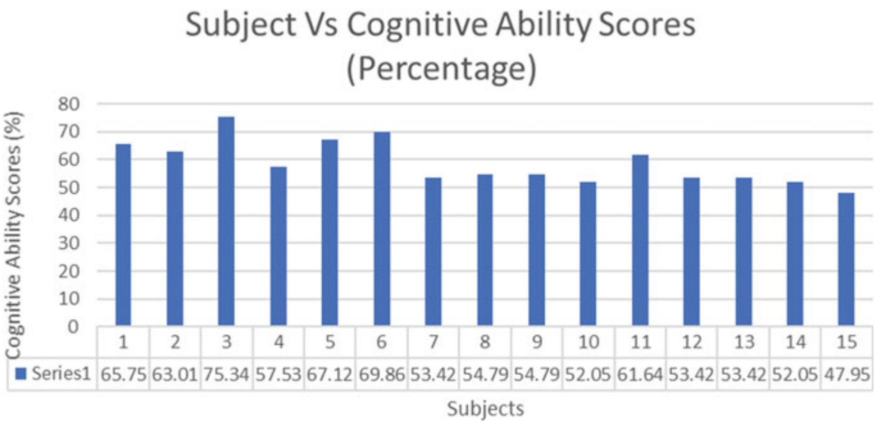

Fig. 2 Percentage of cognitive ability scores

Table 2 Class intervals and performance of subjects

Class interval	Frequency	Title
Poor (35–42)	9	Poor
Good (43–50)	4	Good
Very good (51–57)	2	Very good

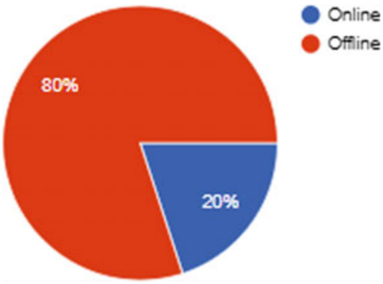

Fig. 3 Pie chart depicting the preferred mode

the potential of the subjects performing online and offline also can be achieved. All the tasks provided matched the profiles of the subjects. An issue with questionnaires, however, is that respondents can lie because of social desirability. Most people want to portray themselves with a positive image and so they may lie or bend the truth to look nice, but here a comparison of the quantitative and qualitative data strengthens the output obtained.

4.2 Multi Criteria Decision Making

Multi-Criteria Decision making is most relevant to solve issues that are described as an option between alternatives. It has all the features of a valuable tool for decision support: it helps us concentrate on what is relevant, is rational and clear, and is simple to use. Here we need to select a subject out of fifteen, but they are having various cognitive abilities with different scores unevenly distributed. A subject with the best and worst cognitive ability has to be found out. The weightages of the different abilities are different. So, to check whether this difference effects the output multicriteria decision making is done. To analyze the accuracy of the study and providing equal weightages to all the cognitive abilities, a multi criteria decision making was done. All the abilities are beneficial in this case. Dividing highest value of each columns with the other values of the same column is done. A normalized decision matrix was obtained, and equal weightages of 12.5% were given, and the performance score was found out as per Table 3.

Here also the performance scores show that subject 3 has the maximum score and subject 15 has the least score. So, the individual abilities and their score weightages are not a criterion for the decision making. An overall score and the tasks performed can be varied according to the area of allocation of workers.

Table 3 Subjects and their performance scores

Rank	Subject	Performance score
1	3	0.789
2	1	0.767
3	6	0.751
4	5	0.731
5	11	0.731
6	4	0.730
7	2	0.642
8	13	0.626
9	12	0.600
10	7	0.584
11	9	0.580
12	14	0.559
13	8	0.558
14	10	0.549
15	15	0.513

4.3 Wilcoxon Test

The differences of the scores of the two matched groups similar to *t* test for two related samples are done using Wilcoxon test. The Wilcoxon test ranks all differences after the differential scores have been determined, regardless of whether the difference is positive or negative.

When sample size $n = 15$ is taken, a critical value against is considered to determine whether the null hypothesis should be rejected or not. The critical value is located by using $n = 15$ and $\alpha = 0.05$. If the observed value of T is less than or equal to the critical value of T, the decision is to reject the null hypothesis. Here the null hypothesis simply suggests that the rankings are same. But from Table 4 it is clear that all the T values are all greater than 25 so thereby failed to reject the null hypothesis. Therefore, it is found out that the rankings are same when each of the abilities were given 20% weightages and the remaining ones with 11.42%.

Table 4 Wilcoxon test data

Cognitive ability	W-	W+	T [Min of (W-) and (W+)]
Visual perception	58	62	58
Attention	28.5	26.5	26.5
Memory	32	34	32
Motor skills	47.5	43.5	43.5
Language	45	46	45
Visual and spatial processing	32	34	32
Executive functions	34	32	32
Learning	38.5	39.5	38.5

5 Conclusion

The study suggests a cognitive skill assessment test in a virtual environment. Subject three has the best cognitive ability and subject one has the least. This pattern is seen when equal weightages were given and also when individual weightages were varied by 11.42%. This suggests that the cognitive ability test conducted is valid and can be used for further studies and the weightages given are appropriate. Subjects three and two can be only selected for the best performance in the virtual mode. This suggests that if a similar task according to the task conducted were given the performance remains same.

The individual cognitive abilities also called as brain functions have to be balanced in a similar way that the end score must be maximum. The individual performs a few tasks in a specific cognitive ability but failed to perform in other, makes a difference in the score. So, a subject must try to develop his skills which he lacks to improve the overall performance. A feedback of the score in each section can be made available and can train the subjects for respective tasks.

The tasks as per human–machine interface required in different scenarios can be modified, then the performance varies among the individuals. Based on that new recruitments, allocation of specific tasks to a subject can be done. As this is a virtual assessment this will be relevant in this time.

The reason for the reduced performance outputs can be the online mode of test conducted. The reason for lower scores can be this transformation from online to offline as per the experimental results and feedback questionnaire. From the literature conducted, there are a wide variety of abilities required for the subjects to perform certain tasks. These tasks can be complex and based on the skills it varies from one subject to other. Identifying these skills based on this study can be done with certain modifications in the tasks given. An ergonomic friendly work atmosphere can also be designed based on the cognitive aspects studied, thereby increasing productivity.

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Chapter 31
Microbial Growth in Wastes and Its Health Impact on Rag Pickers

Santoshi and U. V. Kiran

1 Introduction

Microbial degradation of solid waste means that micro-organisms, which can serve easily as nutrients in a number of other organisms, break down organic garbage components into an inorganic form. The issue of the garbage dump is worldwide and is as old as the man's existence (Nally & Parr 1984). Severe health problems like the spread of contagious illnesses to people and living animals in the area, arise because these wastes are not disposed of properly (Lorentz et al. 2000). Poor waste management, which can lead to the soil, air and water pollution, is another problem (Nwaoke 2004). Wastes on the roads or rail lines are dumped recklessly in most cities in India and other Asian countries, forming ugly mountains of refuge, blocking roads and traffic posing a severe risk to public health (Falase 2004). Inert materials for example plastic, metals, glass and ceramics are some of the waste, but large quantities are biodegradable waste (Boulter et al. 2002).

Although waste disposal methods like composting, landfilling and incineration are available, open waste disposal persists to be the very first available method in several countries, such as India and other countries. Wastes are left for days or weeks on the streets (open dump), before being discarded or relocated to open land at the final landfill sites without proper sorting (Mbata 2008). When waste is dumped on land, soil segments and sub-organisms such as bacteria, fungi and worms (helminthes) readily colonise waste that degrades or transports degradable (organic) materials into the waste. Most of these microbes (such as Salmonella species, Escherichia coli, Fungi and Protozoans) are potential human pathogens and may cause several health hazards (Falomo 1995). The most significant factors that impact the growth of fungi in both inside and outside environment are temperature, moisture and wind speed

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The microbes may become air-borne through the leachate in order to contaminate the soil and ground water.

Biomedical waste is also dumped in municipal dustbins in many cities. It constitutes a significant source of air, water and soil microbial contamination. If municipal solid waste that included biomedical waste is dumped at a solid waste landfill site, pathogenic micro-organisms may contaminate the surrounding environment. In addition, micro-organisms may also be present in the other components of municipal solid waste. Only 10 percent of hospital waste is considered to be ‘highly contagious’ (UNEP 2002), according to the United Nations Environmental Programme (UNEP).

Aware of the potential health risks associated with waste dumpsites, some individuals earn money by scavenging the garbage for livelihood. Such people are referred to as trash pickers, waste pickers or rag pickers (Medina 1997). Rag pickers also contain bacteria that diminish the waste or inhale offensive smells, in order to take the useable wastages. Some other impact is that garbage collectors may experience irritation in the eyes due to dust molecules or toxic fumes in the garbage leading to coughing, sneezing, skin or fungal infections, respiratory diseases and sharp cuts (i.e. containers, syringes, glass, etc.) (Wachukwu et al. 2010).

2 Objective

- To know the impact and risk factors of rag pickers due to microbial growth in wastes.

3 Microorganisms in Waste

Bacteria, fungi, algae, protozoa, and other larger animals are the pathogens that inhabit the aerobic treatment systems. The growth of any or all species of organisms in a given industrial waste management system is dependent on the chemical characteristics of the industrial waste, the environmental limitations of the specific waste system, and the biological properties of the microorganisms. All the microbes which grow in a given industrial waste management make a contribution to its overall characteristics, both good and bad. If the waste management system is to be properly designed and operated for optimum efficiency, it is important to acknowledge the contributions made to the overall consolidation of organic waste by each microorganism.

Bacteria: The fundamental biological units in aerobic waste management processes are bacteria. The varied biochemical existence of bacteria enables them to be metabolized by most, if not all, organic compounds found in industrial waste. In all aerobic waste treatment systems, obligatory aerobes and facultative bacteria are found. The growth of any species depends on its competitive capacity to acquire a proportion of organic materials available in the system.

Fungi: In stabilizing organic wastes, fungi play a key role. Like bacteria, almost every type of organic compound found in industrial waste can be metabolized by fungi. The fungi are capable of sustaining over the microbes, but they do not prevail under rare climate conditions. Fungi would be visible and help in stabilizing the organic material under normal environmental conditions. But fungi are of secondary significance and are not going to predominate.

Rag pickers have been found to face a number of health risks and threats that they are not even aware of. They are potential carriers of waste-degrading pathogens, which indicate that pathogens that are responsible for causing illness in the body serve as transmission vehicles. Those microbes isolated from the garbage dumpsites have also been isolated from the study, confirming that they are all prospective pathogen (i.e. disease-causing organisms) carriers. For example, Salmonella sp. both the dumpsites and waste scavengers that have been isolated are responsible for causing typhoid and intestinal cramping. Likewise, foodborne illness, skin infections, childhood and young adult acute osteomyelitis may result from Staphylococcus aureus. Pseudomonas aeruginosa can also cause scar and burn infectious diseases and is recalcitrant with certain antibiotics for treatment (Wachukwu et al. 2002).

Escherichia coli, one of the microbes which cause urinary tract infection and gastritis in kids, is another main organism. The endospores forming bacteria such as Bacillius sp. are also present in the waste dumps. Such organisms produce bacteria and are usually found in the land. Though most rag pickers are not well secured and if they have any bruising on the body (i.e. cut), the tendency of such infectious agents to enter the body is evident and the resulting effect will be infectious diseases, body uneasiness and, in certain cases, death (Wachukwu et al. 2010).

4 Microbial Waste Management

In general, waste material can be classified broadly into organic and inorganic waste. Organic wastes (biowastes) are wastes produced by micro-organisms that can decompose and do not, over a long period of time, constitute a major source of pollution. They include paper and plant-based waste products, animal-based waste (excrement, carcasses, droppings, and chicken byproducts).

Non-biodegradable solid wastes, on the other hand, are not micro-organismally degradable. This means that other treatment methods, such as incineration, landfill, and recycling, are used as methods of disposal. Solid waste from the metallurgical and smelting industries (abandoned vehicles, motorcycles, vehicle parts and scrap metals, iron, zinc, aluminium sheets and other metals, machine parts) are examples of this group of solid waste; solid waste from the construction industries (sand, gravel, bitumen waste, concrete and waste building materials); solid waste from the plastic industry (plastic buckets, cable waste) (Adebayo and Obiekezie 2018).

One of the main ecological concerns causing extensive pollution and a risk to public health has been solid waste from human activity (Jha et al. 2003). In the last few decades, there is been a substantial growth in waste generation in India.

This is essentially due to the rapid population increase and economic development (Singhal and Pande 2001). In Tiruchirappalli city the amount of waste produced per day would be approximately 408 tons (Anon 2006). Waste product is a menace in the air, water and soil and is also a big threat to the environment. As a consequence, typhoid, dysentery, fever, enteritis, cholera and diarrhoea severe form of diseases are caused. Due to the inability of municipalities to handle the large amount of waste, it is very normal to expect lots of trash lying in a chaotic way inside and outside the cities (Kansal 2002). Rag-pickers are individuals who find 'rags' to be chosen for their living through dustbins. In general, rag-pickers consist of male, female and children who are uneducated and poor. Even so, they help society by discarding a large percentage of the waste generated in a community and thus lowering the amount carried by the local governments responsible for proper management of waste. In poor, unhygienic conditions, they live in urban slums and are exposed to various pathogenic micro-aerosols or the nature of their invasion, which may lead to the occurrence of various diseases. Together with the lack of suitable safety equipment, plenty of fleas and offensive odours at waste disposal sites make the work place environment more unhygienic. Polyethylene, newspapers, plastic or glass bottles, rubber products, and hazardous and non-hazardous materials are collected by rag-pickers from dustbins and dumping sites, making their activities in danger. They are exposed to diverse bacterial infections during their activities (Ray et al. 2004) along with the various toxic substances that can cause illness. In addition, many such components of society are confronted with social abuse, including the expansion of sexually communicated illnesses like AIDS, which can lead to many social problems. They also pick up intoxicating habits easily, such as chewing tobacco, smoking, use of drugs and liquor. For waste-picking, rag-pickers do not ever use masks or gloves for protection. They wear regular rubber sandals (usually gathered from dustbins) during their job.

All kinds of pollution are caused by inappropriate municipal solid waste disposal and management: air, soil, and water. Recklessly disposal of garbage pollutes the supply of surface and ground water. Municipal solid waste clogs drains in urban areas, creating stagnant water during the rainy seasons for insect breeding and flooding. Uncontrolled combustion of municipal solid waste and inappropriate incineration make a significant contribution to urban air pollution. Green-house gases are produced by the decomposition of organic waste in dumpsites or untreated leachate pollutants that surround the soil and water bodies. Safety concerns arising from inappropriate waste management system also exist. The waste attracts insect and rodent vectors or can expanded illness such as cholera and dengue. Using polluted water by municipal solid waste for bathing, the cultivation of food and drinking can also expose individuals to diseased organisms and other toxins. The U.S. Public Health Service has recognized 22 human diseases related to an inappropriate waste management system. Rag pickers are rarely secure from direct contact and injury in developing countries, and the co-disposition of hazardous and hospital waste with municipal solid waste poses serious health hazards. Exhaust fumes from waste disposal vehicles, dust from treatment and disposal and open waste incineration also contribute to general health issues. People know that their health is affected by poor sanitation, particularly in emerging and low-income countries where people is more ready to pay for sustainable development (Alam and Ahmade 2013).

The mixture of untreated hazardous waste from industries with municipal waste poses possible risks to human health. Direct health hazards largely concern workers in this field who, to the extent possible, need to be protected from contact with waste. In dealing with waste from clinics and hospitals, there are also various risks. The major health hazards for the common person are indirect and emerge from the reproduction of infectious diseases, mainly flies and rodents. Allergic respiratory diseases, gastric illnesses, bacterial infections, musculoskeletal diseases and injuries are mainly suffered by labourers and garbage collectors managing the garbage (Alam and Ahmade 2013).

Those who drill the waste landfill sites are the rag pickers who search for the buried treasure in the trash and turn trash into wealth, which serves as an income source for them, where extremely poor young men are involved. There are several health risk factors for this form of occupation. During rag picking, rag pickers do not have enough safety gear and are not usually well secured and go around with dirty clothes and worn-out sandals (Chandramaohan and Ravichandran 2009). The disaster is that garbage collectors are unaware of this profession's health risk factors. The fungal strains that are isolated from the waste are causal factors of various types of diseases. In many cities, there has not been a proper waste segregation system at source. The management has not ever trained people to segregate waste at the source, and no dust bins have been provided to the households to segregate the waste. It was noted that the waste heaps continue to stay uncovered for weeks at the open landfill sites and that is sufficient for bacterial pathogens not only to reproduce and cause infection for the labourers but also for the whole population of the area.

5 Conclusion

The focus of the study was microbial growth in wastes and its health impact on rag pickers. In this research, it is clearly stated that by searching waste scavengers pull out the reusable materials from the waste. It was also found that the amount of garbage produced per day by each residential has increased with the growth in the populace and the increasing demand for meals and livelihood. Waste from households and the community that is not treated properly, especially harmless end products and other liquid and solid waste, poses serious health effect and leads to the spread of infectious diseases mainly among those who pick rags.

Appropriate waste disposal has to be conducted in order to make sure that it will not affect the environment and will not cause health hazards to persons who do such work. It is necessary to properly segregate waste at the domestic level and make sure that all organic matter is kept aside for composting, which is definitely the best way to eliminate this segment of waste properly. In fact, the organic portion of the waste produced dissolves more easily, attracts insects and causes illness. It is possible to compost organic waste and then use it as fertilizer. For impact prevention, these steps may be taken:

- Waste production should be reduced.
- Encouraging the making of products that minimize the production of waste after use.
- Material reuse and restoration should be enhanced.
- Encouraging the use of bar codes and guidelines for recyclable plastic to facilitate the classifying and reuse of plastic packages.
- Municipal governments are raising their public service level in terms of waste sorting.
- Knowledge for manufacturers, the community and for individuals working in the waste management sector should be enhanced.
- Working to promote the use during the manufacture of goods of less dangerous alternatives to toxic materials.
- Legislation should be enhanced in the waste sector.
- Hospital waste collection at collection centre must be secure carefully and environmentally friendly.
- The probability of using these waste collectors in a way which will be economically beneficial to the waste pickers and society can be discussed by the local governments or other civil society. Protection from poor hygienic practices and addiction, they can be adequately educated and trained. Suitable proposals for monitoring and making use of these informal waste collectors should be made by either the government or non-governmental bodies.

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Chapter 32
Musculoskeletal Disorder and Body Parts Discomfort of Farm Women in Paddy Storage Activity of Assam

Mira Kalita, Ruplekha Borah, and Nandita Bhattacharyya

1 Introduction

Storage of paddy grains is one of the most drudgery prone post harvest activity of Assam, which is predominantly performed by rural women. Post harvest activities where farm women are involved in India includes threshing, sun-drying, sieving, winnowing, cleaning, collecting and storage of produce, storage of seed, grading, and packing for sale. The storage activity comprises of three sub activities which are performed in sequence. Standing and bending postures were adopted by farm women in the paddy storage activity. Bending posture was adopted for collecting the grains to the basket, and standing posture was adopted for carrying and unloading the grains. The farm woman usually carried more than 16 kg of grains at a time and during the operation by adopting an awkward posture. In developing countries like India the workers suffer from assorted health problems due to adoption of awkward postures and carrying heavy loads (Chattopadhyay et al. 2009; Mukhopadhyay 2008; Sett and Sahu 2009). They concluded that work related musculoskeletal disorders (WMSDs) resulted from frequent trunk bending, twisting, and repetitive handling of load at a time and women have a higher prevalence rate of work related musculoskeletal disorders (WMSDs) than that of men. Musculoskeletal disorders (MSDs) are important causes of work incapacity and loss of workable life of farm women. Keeping this in mind an attempt was undertaken to assess work related musculoskeletal disorders (WMSDs) and body parts discomfort (BPD) of farm women in paddy storage activity.

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2 Methodology

The present study was conducted in Jorhat subdivision of Jorhat district, Assam. Two development blocks namely North West Development Block, Dhekorgorah, and Jorhat Development Block, Bagh-Choong, were purposively selected for the study. Thirty farm women in the age group of 25–35 years who had been involved for last 10 years in paddy storage activity were selected for the purpose of study. The farm women who are non-pregnant, non-lactating and having normal blood pressure without any major illness were selected for sample. Incidence of musculo-skeletal problems were identified by Nordic Musculoskeletal Questionnaire (NMQ); a 5 point scale was using to identify the work related musculoskeletal disorders (WMSDs) or record intensity of pain in different parts of the body viz. 5, 4, 3, 2, 1 as 'very severe', 'severe', 'moderate', 'mild', and 'very mild' respectively. Corlett and Bishop's (1976) body part discomfort (BPD) scale was applied to identify the zones of discomfort in different body parts. The intensity of pain or different types of discomfort was measured by utilizing the body part discomfort (BPD) scale. The scale consists of markings from 1 to 10. Marks were put according to the intensity of pain. '1' indicates the onset of discomfort/pain or just identifiable discomfort/pain in body parts, '5' indicates moderate discomfort/pain, whereas '10' indicates maximum or intolerable discomfort/pain. A '0' in the scale means no discomfort at all. Grip strength of the farm women before the activity and just after completion of the activity for both left and right hands were recorded and their mean was calculated. A measurement was taken with the help of a Grip Dynamometer and was used to determine the muscle strength of the subjects.

Paddy storage activity

3 Results

Personal and demographic characteristics of farm women revealed that cent per cent respondents were literate and sixty six per cent respondents belonged to nuclear families. Majority of the respondents (82%) belonged to marginal farmers having 1 acre of land for paddy cultivation. As regards to age of the respondents, 88% falls in the age group of 30–40 years.

3.1 Musculoskeletal Disorder of Farm Women in Paddy Storage Activity

A considerable number of adverse health conditions, including musculoskeletal disorders, are linked to agricultural work. In-spite of technological advances, a large number of workers perform heavy manual material handling (MMH) task by conventional tool and techniques especially in India. The agricultural workers repeatedly perform lifting, pulling, twisting, and bending motions that exert force on the musculoskeletal system of the body and thereby leading to fatigue and pain (Singh et al. 2010). Assessment of exposure levels to MSDs risk factors can be an appropriate base for planning and implementing interventional ergonomics programs in the workplace. To improve the efficiency of the workers, their posture needed to be assessed and corrective measures should be adopted to avoid the musculoskeletal disorders (Singh 2010).

Incidence of pain in different body parts due to storage of paddy grains is presented in Fig. 1. The farm women had 'very severe' pain in shoulder (86.66%), low back

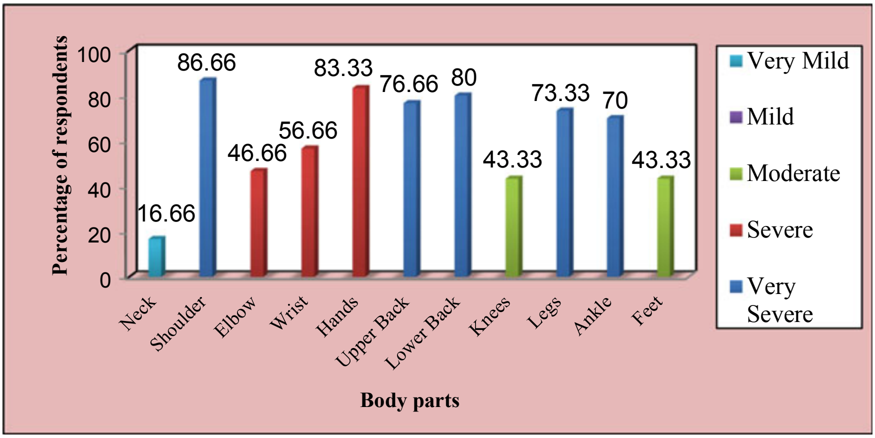

Fig. 1 Musculoskeletal disorders of farm women in paddy storage activity

(80%), upper back (76.66%), leg (73.33%), and ankle (70%). Farm women experienced 'severe' to 'moderate' type of pain in hands (83.33%), wrist (56.66%), upper arm (46.66%), calf muscles (43.33%), and knees (43.33%). Less than seventeen percentages of the respondents complained 'very mild' type of pain in neck (16.66%). The occurrence of pains in different body parts was due to the fact that unloading the basket to storage structures required maximum force for lifting heavy load. Similar findings were also observed by Sett and Sahu (2009) that the female brick molders felt pains in lower parts of their body, highest being in the low back (86%) and leg (86%). Pains suffered by female brick carriers on their upper parts of their body such as head (96%), neck (97%), and shoulder (88%) were due to carrying heavy loads on heads. In such conditions, some of the work related musculoskeletal disorders (WMSDs) risks factor may be reduced by an ergonomic intervention with relatively low cost, other risk factor that are inherent in the tool design, working environment and task itself can be remedies. Damage to the knees and fracture was also reported by 10 and 22% of males and 16 and 20% of females reported miscarriage due to manual material handling (MMH).

3.2 Body Parts Discomfort of Farm Women in Paddy Storage Activity

Subjective discomfort rating for task-related factors tends to be affected by at least one of the risk factors including working posture, frequency, and force exertion. There is an association between the risk of musculoskeletal disorders and range of motions (ROM) with discomfort (Dul et al. 1994). Hands above shoulder level increase discomfort even in light weight conditions. The intensity of pain feeling/discomfort feeling was measured by utilizing the body part discomfort (BPD) scale. In identifying the zones of discomfort in different body parts in storing paddy grains, it was found that more discomfort zones were shoulder, elbow, wrist, low back, and legs of the body (intolerable pain/discomfort) by more than 80% of farm women followed by moderate pain/discomfort in neck, upper back, knee, and ankle. Farm women experienced more discomfort in the upper parts of the body, such as the head, neck, shoulders, and arms than that of the lower body parts. The difference is due to the fact that the farm women carry heavy loads by adopting awkward body posture. Barman et al. (2009) conducted a similar study on female fish processing workers in West Bengal and found that maximum workers' response to their discomfort was of moderate type in different region (e.g., wrist, neck, shoulders, arm, lower back, etc.).

The use of conventional tool and techniques for paddy storage activity was not acceptable by farm women, and modification of both tool and techniques is very essential to reduce disorders and improving health and wellbeing.

Table 1 Grip strength (kg) of the farm women in paddy storage activity

Grip strength (kg) of the farm women		
	Left hand (kg)	Right hand (kg)
Before activity	13.00	12.85
After activity	12.02	11.30
Percentage changes of grip strength	7.53	12.06

3.3 *Grip Fatigue/Strength of Farm Women in Paddy Storage Activity*

Decrease hand grip strength of any workers or subjects is due to general muscular fatigue at the end of day's work. Muscular fatigue and wrist pain could contribute to hand pain and work related musculoskeletal disorders. Proper gripping of tools or equipment is essential for reducing hand grip fatigue and to minimize bending posture while doing a ground or floor level activity. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations of awkward postures, and the grip should not require excessive force (NIOSH 1994).

Grip strength of the farm women was observed to be different for both the hands. The left hand of the respondents had more grip strength (13 kg) than right hand (12.85 kg). There was a decrease of grip strength during the activity (Table 1). The percentage change of grip strength was found to be 12.06 in right hand and 7.53 in left hand respectively. The percentage reduction of grip strength was found to be less in left hand. Similar findings were observed by Mehrotra and Sharma (2001) who found that percentage change in grip strength of right hand was 16% and left hand was 14.7% indicating that the reduced strength of left hand grip is less. Change of grip strength can be increased by providing handles to the basket. A well-balanced tool with a properly designed grip or handle instantly feels comfortable in the hand.

4 Conclusion

It was found that a distinctly harmful effect on musculoskeletal system of the farm women in paddy storage activity. The working methods should be changed as soon as possible. If the farm women continued they suffer from lot of work related musculoskeletal disorders (WMSDs) related to neck, trunk, shoulder, upper arms, lower arms, and wrist in the near future. From the observations, it can be concluded that movements of different body parts and adoption of traditional tool and techniques leads to stress on musculoskeletal system or leads to muscular fatigue of farm women during paddy storage activity. In such conditions muscles are unable to function properly. For most efficient functioning of muscles, musculoskeletal disorder and discomfort in different body parts of farm women should be minimized through ergonomic intervention.

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Chapter 33
Occupational Health Hazards Associated with Fish Dressing Operation: A Case Study of Ratnagiri Fishing Harbour

J. K. Khurdal, V. V. Aware, A. U. Pagarkar, P. U. Shahare, R. R. Potdar, and S. V. Aware

1 Introduction

India ranked third in fisheries and second in aquaculture in the world with total fish production of 12.6 million metric tonnes, which constitutes about the 6.3% of global fish production. Fisheries and aquaculture is one of the important sector of food production in India, which not only provides the nutritional security but also provides employment and livelihood support to 14.5 million people. At present, fish and fish products emerged as largest group, contributing about 20%, in agricultural exports and nearly 10% of the total exports from India that garnered foreign exchange worth Rs. 45,106.89 crore in value. Nevertheless, the national average annual consumption of fish and fishery products in India is very less, about 5.00 kg (Annual Report 2017–18). Before final fish product delivered to the customers, the harvested raw fish needs to be processed for development of flavour, texture, colour, and improved storage characteristics of the products. The associated operations in fish processing are dressing, washing, degutting, salting, fermentation, drying and smoking.

The fish dressing is one of the important operations in raw fish processing and carried out under low temperature conditions. A cold environment may be a significant health risk factor such as, respiratory symptoms, musculoskeletal diseases and skin diseases (Amaravathi et al. 2014). The term Musculoskeletal Disorders (MSDs)

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applies to a broad range of disorders and injuries of the musculoskeletal system. These may occur when the demand of an activity exceeds the capacity or limitations of the musculoskeletal components (Bazley et al. 2015). A number of factors such as work conditions, age, safety training, experience and fish dressing workplace design have been found to be either directly or indirectly responsible for occupational health hazards. Also, the traditional fish dressing process involved the exposure of foul smell, blood, cut parts of fish etc. to the workers which make them uncomfortable and problematic to their health.

In the Konkan region of Maharashtra state, the fish dressing operation, carried out mainly by women workers that included the removal of head, fins and tail part of raw fish. In fish dressing industries, fish dressing operation is being carried out manually on a galvanized iron (GI) pipe frame having an arrangement for keeping a plastic crate on right and left side of the frame for storing raw undressed and for dressed fish, respectively (Fig. 1).

At the centre of frame, a cutting blade is fixed for dressing of raw. The women workers used to sit on the inverted crate with a small wooden plank in squatting posture. Continuous and long duration sitting in such awkward posture causes discomfort, leg pain, back pain etc. in women workers. Also, while doing fish dressing operation, their hands are exposed to or come in contact with different sharp body parts of raw fishes that causes cuts and injuries in hands. As fish dressing operation exposed workers to frequent minor injuries that will be harmful in long run. The low temperature at the working environment and frequent contact with ice cooled chlorinated water makes the workers suffer from many other morbidities including frequent respiratory irritation (sneezing/coughing), headache, blanching of hand etc. (Pagarkar et al. 2014). The respiratory and musculoskeletal problems of fish processing workers have been addressed repeatedly (Saha et al. 2006). Keeping these points in view, the study was undertaken to understand the frequency of injury occurrence and the associated factors and to test whether sufferings of workers (due to work or work environment) have any significant contribution to the occurrence of occupational injuries.

Fig. 1 Fish dressing operation

2 Materials and Methods

The fish dressing activity was carried out at low room temperature where workers frequently come in contact with ice, ice cooled chlorinated water, slippery fish bodies, sharp knives etc. Also, the workers were performing the fish dressing activities with bare hands. Only fingers were covered with cloth to have a proper grip to hold the raw fish and to avoid injuries to fingers. The hand protective gloves were used to some extent by the workers.

The study was conducted in Ratnagiri district located at 16.98° N 73.3° E in Maharashtra state of India. During the study, an interview based survey was conducted at fish dressing industry in the Ratnagiri fishing harbour with the objective to study the issues related with health hazards and to identify the drudgery involved in fish dressing operation. The survey involved the personal interviews of the participated workers, for which a questionnaire was prepared, to get the responses from fish dressing workers. The main points included in the questionnaire were description of the fish dressing workplace, workers basic information, and various aspects associated in fish dressing operation. The survey was carried out by visiting five fish dressing sheds wherein 68 women workers (subjects) participated voluntarily. All the participated subjects were briefed about the purpose of the survey and information to be collected. They were advised to give the honest responses to the questions asked during the survey regarding fish dressing workplace and their personal details in a formal way.

The information collected during the survey on the various aspects of fish dressing operation were recorded in the form of ‘Yes’ or ‘No’ responses. The ‘Yes’ response indicated that the apparent absence of any problem associated with the fish dressing operation and ‘No’ response indicated that there exists problem associated with the fish dressing operation that needed to be addressed. The need of modification in the fish dressing workplace and the extent of problem were analysed by rating given to the ‘No’ responses between 0 and 5 scale (0 for do not know or not applicable, 1 for strongly disagree, 2 for disagree, 3 for neither agree nor disagree, 4 for agree and 5 for strongly agree) (Nag 1998). The details of parts of the questionnaire developed for survey are follows:

2.1 Description of the Fish Dressing Workplace

The responses of the questions such as name of the unit, activities carried out by the workers, number of workers engaged in the activity, condition of the fish dressing room etc. were recorded under description of the fish dressing workplace part of the questionnaire. The majority of workforce engaged in fish dressing operation were women, whereas men workers were involved in the material handling tasks, such as loading unloading and washing of plastic crates.

2.2 Workers Description

In this part of the questionnaire, the responses to the questions related to the worker's personal details along with their health status and occupational hazards due to work and fish dressing workplace environment, and working posture adopted during operation were recorded. During the handling of fishes, the workers were exposed to constituents of allergens through inhalation and skin contacts (Chiang et al. 1993).

2.3 Aspects In Fish Dressing Operation

In this part of the questionnaire, the various aspects in fish dressing operation viz. job specialization, skill requirement, ergonomic aspects and working posture were recorded and studied. The information on tools and methods used and position adopted for fish dressing operation etc. were collected from worker's responses. The ergonomic aspect in fish dressing operation was the major part of the study that involved the questions on the fish dressing workplace compatibility with workers dimensions and seating arrangement. Posture adopted in fish dressing operation was analysed, and the reasons for awkward posture were identified. The long hours of awkward sitting posture and fish dressing workplace incompatibility were the main reasons of causing the musculoskeletal pain and discomfort (Nag and Nag 2006).

3 Results

3.1 Fish Dressing Workplace Description

In all the five fish dressing sheds in total 207 women workers were engaged in fish dressing operation and 52 male workers were engaged in loading/unloading and cleaning of raw fish material. It was found that average area of fish dressing shed was 550 m^2 and the average light intensity was 150 Lux. The fish dressing sheds had roof of the metal sheets and cement concrete floor. The average relative humidity in the sheds was 61.2%.

3.2 Workers Description and Occupational Health Hazards

The baseline information of women workers participated in the survey in fish dressing sheds is showed in Table 1. It was observed that 57.3% women workers were in the age group of $\geq$25 years and rest were $\leq$25. The height of 52.9% women workers was $\leq$1585 mm, 77.9% women had weight $\geq$45 kg. During investigation, 72%

Table 1 Baseline information of women workers

S. N	Particulars		Values (%)
1	Age (yrs)	≤25	42.6
		≥25	57.3
2	Height (mm)	≤1585	52.9
		≥1585	47.0
3	Weight (kg)	≤45	22.0
		≥45	77.9
4	Marital status	Married	73.5
		Unmarried	26.4
5	Education	Illiterate	14.7
		Educated	85.3
7	Experience (yrs)	≤5	72.0
		≥5	27.9
8	Working schedule in day (h)	≤6	26.0
		≥6	73.9

women workers had experience of ≤5 years. About the educational status, 85.3% women workers were literate. About 73.5% women workers were married. During investigation it was observed that 73.9% women workers had working duration in day ≥6 h.

The occupational health hazards occurred during fish dressing operation is presented in Table 2. The work and fish dressing workplace related health hazards revealed that among fish dressing women workers, 73.5% women had skin related problems and blanching of hand, 25% workers had respiratory irritation

Table 2 Occupational hazards

S. N	Particulars	Per cent	
		Yes	No
1	Work and fish dressing workplace related		
	a. Skin related problems and blanching of hand	73.5	26.5
	b. Respiratory irritation (sneezing/coughing/cold and fever)	25	75
	c. Body ache and headache	82.3	17.7
	d. Frequent hand injury	55.9	44.1
2	Working posture related		
	a. Back pain	91.1	8.9
	b. Leg pain	85.3	14.7
	c. Body pain	89.7	10.3
	d. Knee pain	83.8	16.2
	e. Neck pain	78	22.0

(sneezing/coughing/cold and fever), 82.3% workers had headache and body ache and 55.9% of the workers had faced frequent hand injuries. The working posture related health hazards revealed that among women workers engaged in fish dressing, 91.1% workers had back pain, 85.3% workers had leg pain, 89.7% workers had body pain, 83.8% workers had knee pain and 77.9% workers had neck pain. It was due to awkward seating position, cold environment and inappropriate use of precautionary measures.

3.3 Aspects in Fish Dressing Operation

Requirement of job specialization

Out of 68 workers, 44.1% women workers responded 'Yes' to the question whether fish dressing was simple and uncomplicated while rest (55.9%) were responded 'No'. The bar graph showing the workers rating about requirement of job specialization in fish dressing operation is given in Fig. 2. Out of 55.9% workers, 2.6% workers response was "strongly agree", 78.9% workers response was "agree", 10.5% workers response was "neither agree nor disagree" and 7.9% workers response was "disagree" to the tools and methods used for fish dressing were specialized. 73.7% workers response was "strongly agree", 21% workers response was "agree" and 5.3% workers response was "disagree" to the position adopted for fish dressing was not comfortable. This showed that majority of the workers were in agreement

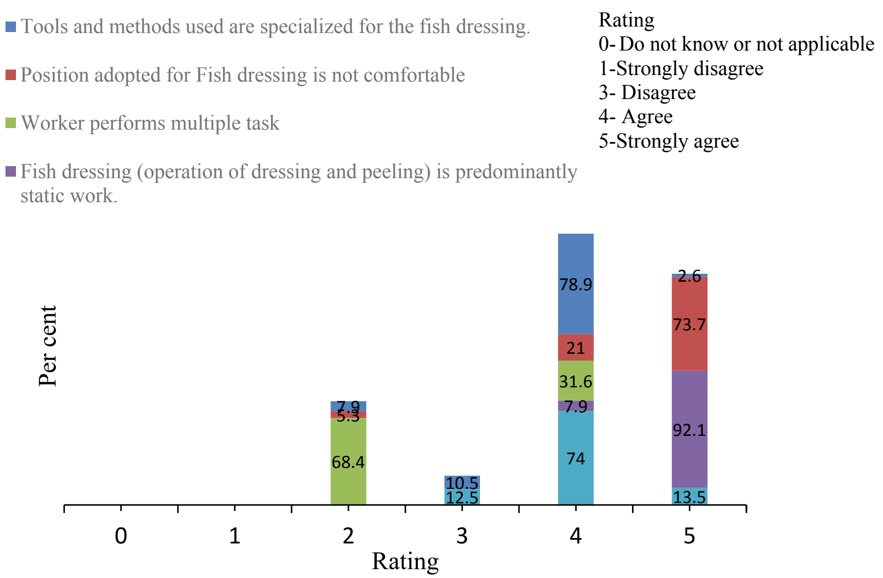

Fig. 2 Workers rating about requirement of job specialization in fish dressing operation

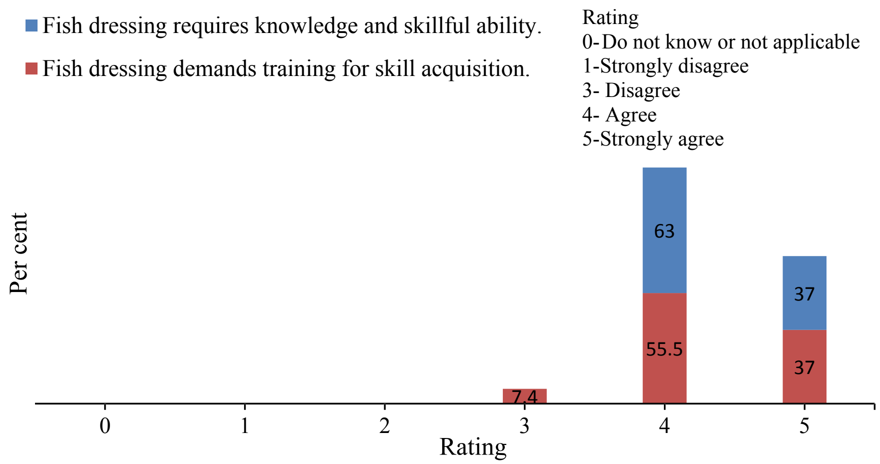

Fig. 3 Workers rating for skills requirement

that the awkward and uncomfortable posture adopted during fish dressing operation. 92.1% workers response was "strongly agree", 7.9% workers response was "agree" that the fish dressing was predominantly static work. 31.6% workers response was "agree", 68.4% workers response was "disagree" that workers perform multiple task. Similarly, 13.5% worker response was "strongly agree", 74% workers response was "agree" and 12.5% workers response was "neither agree nor disagree" that the fish dressing required fixed working position (seating).

Skill requirement

Out of 68 workers, 39.7% workers responded that fish dressing required the elementary skill. The bar graph showing the workers rating for skill requirement is given in Fig. 3.

Out of 39.7% workers, those responded for the question on skill required for fish dressing, 37% workers response was "strongly agree", 63% workers response was "agree" that the fish dressing required knowledge and skillful ability. Similarly, 37% workers response was "strongly agree", 55.5% workers response was "agree" and 7.4% worker responded neither agreed nor disagreed to that the fish dressing demanded training for skill development.

Ergonomic aspects in fish dressing

Fish dressing workplace/fish dressing workplace design

During the survey, the surveyor discussed with women workers about the fish dressing workplace compatibility with their body dimensions. Out of 68 workers, 80.9% workers responded that the fish dressing workplace was not compatible with their body dimensions. Therefore, the fish dressing workplace needed to modify according

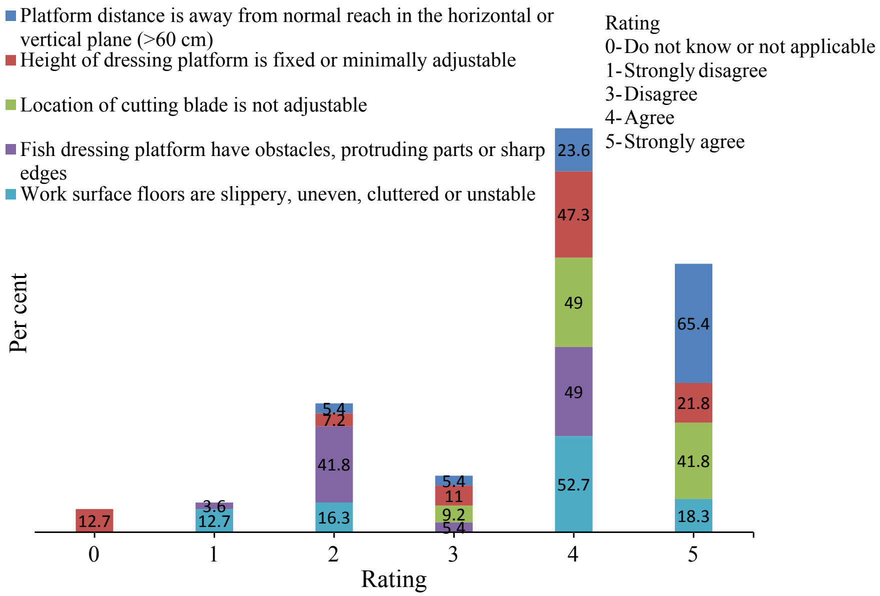

Fig. 4 Workers response about fish dressing workplace compatibility

to their body dimensions. The bar graph showing the workers rating about fish dressing workplace compatibility is given in Fig. 4.

Out of 80.9% workers responded for mismatch of the fish dressing workplace, 65.4% workers response was "strongly agree" and 23.6% workers response was "agree" that platform distance was away from normal reach in the horizontal or vertical plane (>600 mm). About, 21.8% workers response was "strongly agree", 47.3% workers response was "agree" and 12.7% workers were responded "do not know or not applicable" that the height of dressing platform was fixed or minimally adjustable. 41.8% workers response was "strongly agree", 49% workers response was "agree" and 9.2% workers response was "neither agree nor disagree" that location of cutting blade was not adjustable. 49% workers were agree, 5.4% were neither agree nor disagree, 41.8% disagreed and 3.6% workers were strongly disagree that the fish dressing platform had obstacle, protruding parts or sharp edges. 18.3% were strongly agree, 52.7% workers were agree, 16.3% were disagree and 12.7% workers were strongly disagree that work surface floors were slippery, uneven, cluttered or unstable.

Seating arrangement

During the survey the ergonomic suitability of existing seating arrangement was studied. Out of 68 workers, 73.5% women workers responded that the seating arrangement was not adequate for the fish dressing operation. The bar graph showing the rating about seating arrangement is given in Fig. 5.

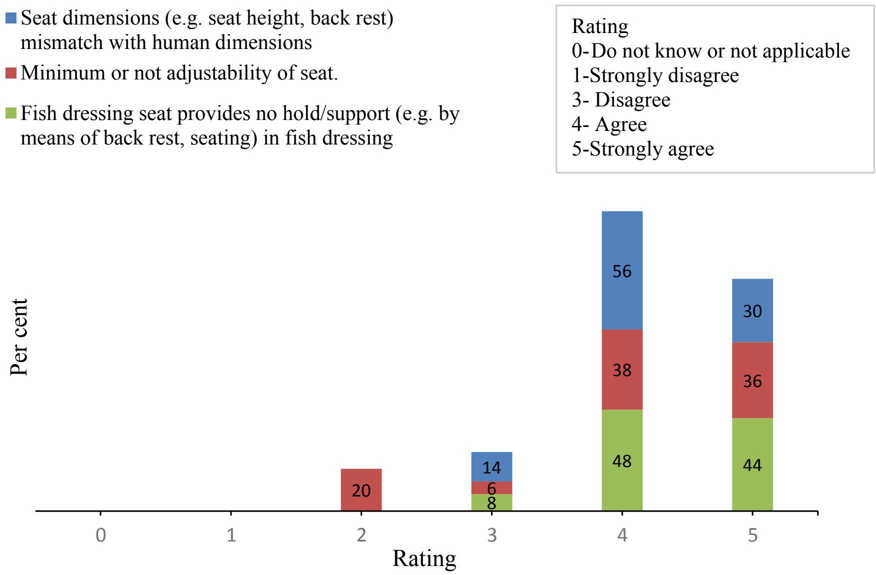

Fig. 5 Workers rating about seating arrangement

Out of 73.5% workers, 30% were strongly agree, 56% were agree and 14% neither agree nor disagree that seat dimensions (e.g. seat height, back rest) mismatched with body dimensions. 36% were strongly agree, 38% were agree, 6% were neither agree nor disagree and 20% were disagree that the seat had minimum adjustability or not adjustable. 44% women workers were strongly agree, 48% were agree and 8% were neither agree nor disagree that the fish dressing seat provided no hold/support (e.g. by means of back rest, hand rest).

Work posture

The working posture of workers during fish dressing operation affected the output capacity as well as the efficiency of worker. Workers were asked about the work posture during the fish dressing operation. Out of 68 women workers, 80.9% workers were responded that the fish dressing did not allow comfortable work posture. Bar graph showing the workers rating about working posture is given in Fig. 6.

Out of 80.9% workers, 56.3% were agree, 14.5% were neither agree nor disagree, 21.8% were disagree and 7.3% responded did not know or not applicable that the neck and shoulder were not maintain at an angle of 15°. 36.7% were strongly agree, 47.3% were agree and 16% were neither agree nor disagree that the fish dressing operation needed frequent movement of wrist. 20% were strongly agree, 56.3% were agree, 10.9% were neither agree nor disagree, 7.3% were disagree and 5.4% were strongly disagree that in fish dressing back position was bent and twisted. 27.3% were strongly agree, 43.6% were agree, 14.5% were neither agree nor disagree and 14.5% were disagreed that the hips and legs were not well supported in seated position while

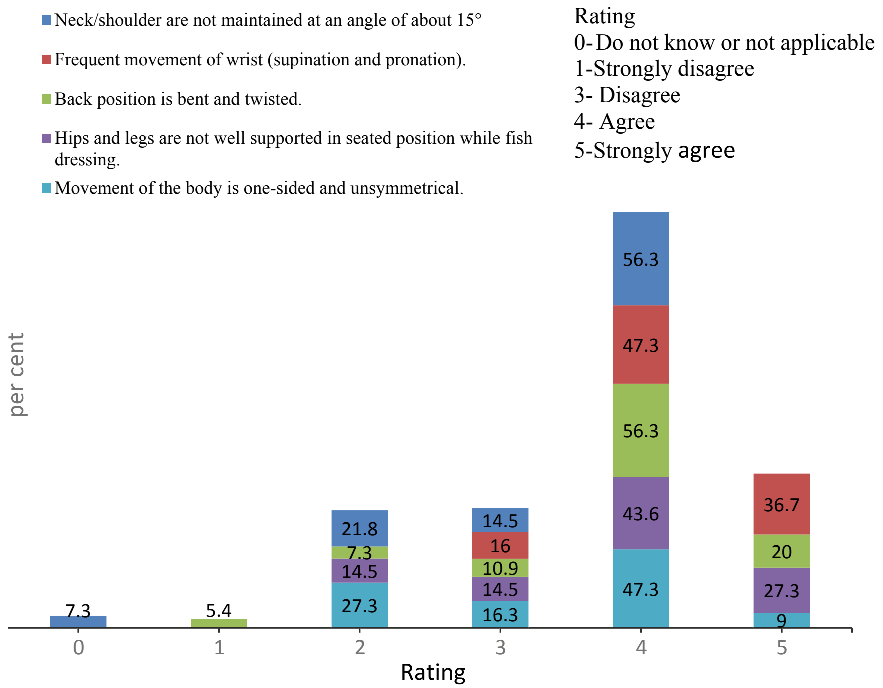

Fig. 6 Workers rating about working posture

fish dressing. 9% were strongly agree, 47.3% were agree, 16.3% were neither agree nor disagree, 27.3% were disagree that movement of the body was one-sided and unsymmetrical.

The bar graph (Fig. 7) shows the reasons of forced posture in fish dressing operation. The workers were informed to report the reasons of forced posture. Out of 68 women worker 60.3% reported that the forced posture was due to cutting blade location, 38.2% reported that it was due to seat design, 57.3% reported that it was due to equipment handling whereas 72% reported that the forced posture was due to the workspace or fish dressing workplace.

4 Conclusions

Fish dressing share many similarities that are attributed to the poor work conditions, which pose a variety of health hazards to the workers. This study highlighted the fish dressing needs to mitigate the health hazards. The interventions requires remedial attempts to reduce the direct contact of ice cold chlorinated water, integrating with change in the methods of fish dressing to improve the work posture and designing the fish dressing workplace according to the workers compatibility to reduce the

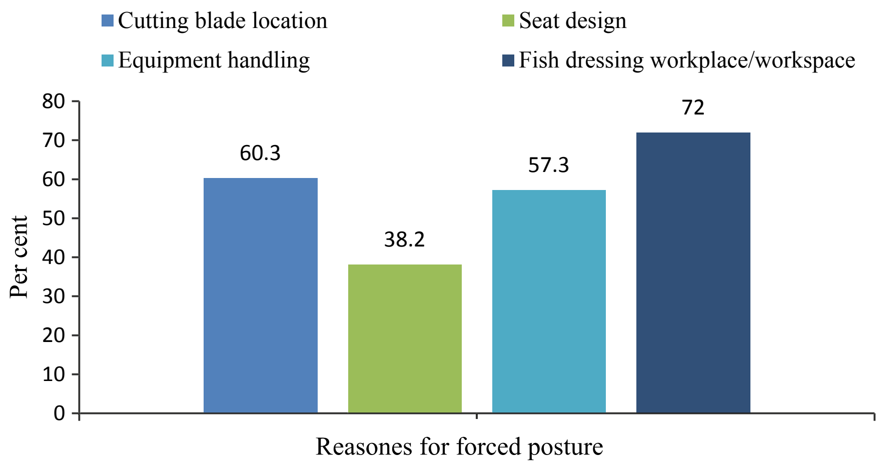

Fig. 7 Workers response about reasons of force posture

musculoskeletal disorders. Designing the fish dressing workplace according to the workers compatibility was the practical way to control the some of the health hazards in the fish dressing workplace.

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Chapter 34
Occupational Health, Safety and Ergonomic Concerns in Small Scale Spices Grinding Mills

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1 Introduction

Ergonomics aims to make sure that tasks, equipment, information, and the environment suit each worker, and it seeks to minimize adverse effects of the environment upon people thus enabling each worker to maximize his/her contribution to a given job (Qutubuddin et al. 2013a). Occupational health and safety (OHS) seeks to strengthen the working capacity of the operators and to identify, assess, and avoid risks and hazards within the work environment. Ergonomics combines all these issues to improve worker competence, health and safety, and maintain the industrial production through better design of the work place and work environment (Qutubuddin et al. 2013b).

Several studies in the literature report that workplace environment in many industries in the unorganized sector is unsafe and unhealthy in India. Problems are encountered such as poor workstation design, mismatch between furniture, poor lighting, noise, ventilation, insufficient safety measures, and inadequate use of personnel protective equipment. Workers in such environments are prone to occupational health issues, and it influences the performance (Qutubuddin et al. 2013a). Small-scale industries (SSIs) with less than 50 employees are a major contributor in the national and regional economic development in most countries (Vinberg 2020) and account for large amount of employment. The SSIs in unorganized sector caters to the local markets and are characterized by several occupational health, safety and ergonomic (OHS&E) concerns (Nikhilkumar et al. 2020) in the work station design and work environment affecting the performance of workers and decreased productivity.

India is a multi-cultural country and enjoys a variety of traditional cuisines related to each state; many of such variety of dishes are very spicy. The main ingredient of such food is spices in dried form such as chilli, turmeric, coriander, and cinnamon due to high demand of spices, spice grinding mills have become one of the contributors

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to the economy and employs lakhs of laborers (Babel and Rajvanshi 2013). As the process of spice making involves grinding, the laborers are continuously exposed to very high dusty environment causing serious concerns about the pulmonary function problems (Chan et al. 1990). Indoor air pollution at workplace is identified as one of the major problem in developing countries (Noor et al. 2000). Prevalence of musculoskeletal disorders due to awkward postures, manual material handling, poor layout design, and inappropriate tools are also a major issue in such industries.

In the present study the grinding mills manufacturing spices like chilly, turmeric, coriander powder are selected as a case study. The grinding mills selected were located in North Karnataka and operate throughout the year. Different methods are available like hammer mills, two stage pulverizes, customized grinding system with pneumatic conveying systems. Hammer mills are mostly used in small scale and unorganized or informal sector. The grinding capacity of each machine is about 150–200 kg per hour. Some of these mills work as subcontractors to the large companies and supply powdered chilly, coriander, and turmeric in bulk quantity. Some of the mills also market the powder in small packaging under some local brands.

1.1 Objective of Study

The present study was undertaken to evaluate the occupational health safety and ergonomic concerns with respect to the workers workload, discomfort and pain, use of PPEs, and other ergonomic deficiencies in the work practice.

2 Methodology

The present study is carried out initially by using a questionnaire to get information on self-reported problems. More information about the work process, methods, environment, and use of PPEs was collected through observation, discussions, and interviews. Data was analyzed through frequency and percentages. For conducting postural analysis the various working postures are recorded through video and still photographs. The noise levels at the various machines are recorded using a LUTRON sound level meter SL-4023SD.

The demographic characteristic of the workers is presented in Table 1. The average age of the respondents is 29 years with a standard deviation of 8.84. The height and weight of the respondents is measured to determine the BMI. The average experience is 5.48 years with standard deviation of 4.86 years. The duration of work is 8–10 h per day. About 56.25% workers are female and the rest are male.

Table 1 Physical characteristics of the subjects

Subject/Occupation	Total workers	Male (%)	Female (%)	Mean age (SD)	Mean height (SD)	Mean weight (SD)	Mean experience (SD)	Duration (hours)	Smokers (%)
Grinding mill workers	32	14 (43.75%)	18 (56.25%)	29.91 (8.84)	165.6 (7.7)	58.75 (4.09)	5.48 (4.86)	8 ± 1.2	20 (62.5%)

2.1 Manufacturing Process

The spice grinding mills manufacture a variety of spices like chili, turmeric, and coriander powder. The present study is focused on the manufacturing of chilly powder. The process of manufacturing chili powder consists of three stages, i.e., drying, milling, and packing.

- **Drying**: The first step in any grinding process is drying of spices. The raw chilly procured from the market or from farmers is spread out in the open yard under the sun for about 4–5 h. This is necessary to remove the moisture content in the raw chilly. After complete drying the chili is ready to be grinding.
- **Milling**: The dried chilly is fed into the grinding machine for milling by the operator. The workers collect the dried chili from the open yard and carry it in baskets to the feeding area of the grinding mill. The machine operator picks up the baskets full of chilies from the workers and feeds the chilies slowly into the hopper. The women wait for the operator to pick up the second basket, and this way the work continues. The powdered chili is collected through a piped conveyor at one corner of the shed. This powder is coarse and is fed again into the grinding mill.
- **Second milling**: In this process the granular chilly collected from the first operation is collected in baskets and carried to the grinding mill again. The mesh size in the machine is changed for fine powder. It is to be noted that the workers carrying chili powder are totally unprotected with any safety devices or protective gear. The baskets of coarse chili powder are collected by the operator and fed again into the hopper of the grinding mill. The powdered chilly is collected at another place for a next round of milling.

The detailed study of the pulverizing mill is conducted by considering various ergonomic and Occupational Health and Safety factors like the working environment, machines, methods, workers, and management.

2.2 OHS and Ergonomic Problems in Grinding Mill

The first step in this study was to identify and analyze the factors that contribute to OHS and ergonomic problems. A cause and effect diagram (Fig. 1) shows the various factors leading to the occupational health safety and ergonomic problems in the grinding mills.

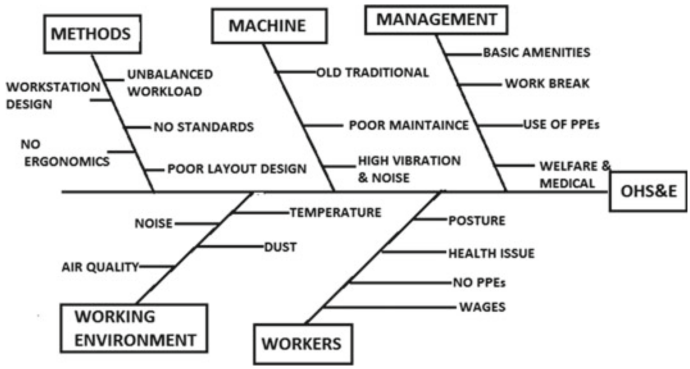

Fig. 1 Cause and effect diagram showing ergonomic problems

2.2.1 Working Environment

The work environment in the grinding mills consists of the following parameters:

- **Dust**: The working shed of the pulverizing mills contains fine air borne particles of chilli dust. The workers are totally exposed to dangerous substances and have serious health repercussions. Irritation to eyes, swollen eyes, skin allergy, and infections are quite common health problems. The other common health problem is respiratory problem.
- **Noise**: The grinding requires about 60 HP of power, and the noise levels are very high. The absence of personal protective devices makes the situation even worse. Many complaints were also reported related to hearing, increase blood pressure due to continuous exposure to noise and annoyance.
- **Temperature**: The workers are exposed to high levels of heat stress. The workers in the drying process continuously work under hot sun as the day temperatures in this region during summer record up to 44°. The indoor temperature is also high due to the hot environment and also due to fine dust particles of chilly in the air and poor ventilation.

2.2.2 Workers and Management Issues

The workers are usually illiterates and work in these grinding mills due to unemployment and no other opportunity to get employed. Many workers leave the job once they get another opportunity because of the adverse working conditions and poor management practices. The workers work in a shift of 8–10 h and are paid on daily wages. The workers have always complaints about the wages paid. Considering the nature of work under extreme conditions they deserve better wages and working facilities.

From the responses of the workers it is found that the wage system followed by the company also contributes to dissatisfaction of the workers. Proper rest breaks are necessary in between work. The management is responsible for providing better conditions, provision of PPEs, and other welfare facilities, which is seldom seen in these grinding mills. The work involves adapting to awkward postures, health issues, and poor workstation and payout designs contributing to the overall discomfort of the workers. Small measures like providing good sanitation, drinking water, a place to rest, and medical facilities should be provided.

2.2.3 Machines and Methods

The spice grinding mills consists of hammer mills and packaging machine for making small pouches of 50, 100, and 200 gm. For bulk packaging is done manually. At the chilli machine, the operator has to stand throughout the shift for feeding the chili to the machine. The work place is not designed according to the anthropometry or considering ergonomics. It involves working above the shoulders. This results in risky awkward postures, heavy handling of loads, and continuous repetitive movements.

Similarly in the packaging section where chili powder is packed into the polythene packets, most of the work is done manually where the worker is positioned in unnatural postures sitting on the floor. Even though the workers are exposed to high risks due to the chili powder and its effects on their health, no proper safety measures are undertaken by the management.

3 Results and Discussion

3.1 Body Discomfort Survey

The preliminary study indicated that the workers are uncomfortable at the workplace due to various factors like work postures, unbalanced work load, working methods adapted, work station design, and manual material handling. Correct work postures have a significant role in preventing the development of MSDs (Qutubuddin et al. 2013a, b; Chan et al. 1990). It was observed that the workers were practicing awkward postures in many activities thus leading to development of MSD's.

The information relating to the prevalence of work related MSDs is collected through a questionnaire. The information was collected through personal interviews with the workers directly among 32 subjects on a scale of 1–5.

The information obtained through body discomfort survey is shown in Fig. 2. As can be seen majority of workers reported irritation and discomfort in eyes (80%), followed by 72% discomfort in lower back and 68% discomfort in upper back. Shoulder discomfort accounted for 63%, and the neck discomfort score is 42%. The higher level of discomfort in upper limbs and back is an indication of the extreme awkward postures in which the workers are subjected to work. High discomfort is

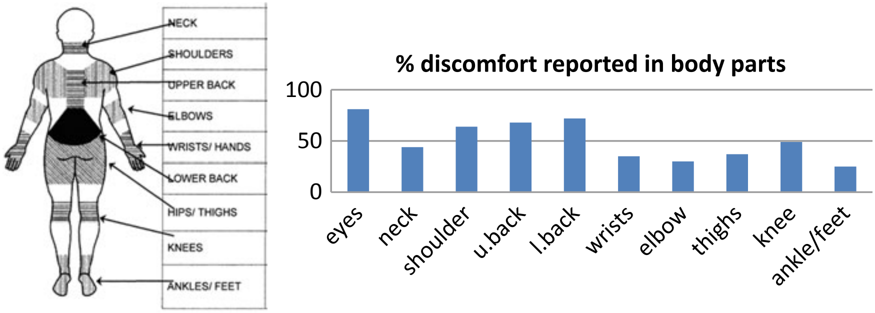

Fig. 2 Summary of body discomfort survey among grinding mill workers

indicative of prevalence of MSDs in the long term, if not corrected early (Qutubuddin et al. 2013a; Chan et al. 1990).

The detail working operations in the grinding mill and the activities carried out in each operation is highlighted in Table 2.

Table 2 Activities carried out by grinding mill workers

Operation	Activities	Remarks
Drying	1. Carrying the Chilly/Turmeric Sacs from stores to open yard for drying under sun (25–50 kg) 2. With a wooden spreader, spreading the spices on the floor for drying 3. Other activities such as cleaning, sweeping, cleaning, filling the baskets etc.	• Manual material handling of Sacs • Awkward postures during handling • Bending, twisting, and turning during spreading of chilli and turmeric
Grinding	1. Carrying the spices baskets from open yard to Grinding mill 2. Loading the dry chilli from baskets to the hopper of machine (6–10 kg) 3. Filling the coarse chilli powder into baskets and carry to grinding mill for fine grinding (8–10 kg)	• Manual handling of baskets sideways or overhead as per their comfort • Mostly work done by women • Awkward/unnatural work postures prone to developing MSDs • Exposure to fine spice dust leading to respiratory problems • Excessive noise
Packaging	1. Filling the powdered spices into packets 2. Weighing and sealing of packets (500 gm to 5 kg) 3. Moving the sealed packets to stores	• Awkward sitting postures • Working without PPEs

Table 3 Health issues encountered by grinding mill workers (n = 32)

Health problem	No. of workers	Percentage
Sneezing and coughing	27	84.37
Sweating	25	78.12
Headache	19	59.37
Nausea	05	15.62
Watery Nose	14	43.75
Itching and irritation of eyes	26	80.00
Skin burning	29	90.62

3.2 Health Issues Encountered by Workers

Spice milling workers are exposed to various health issues and hazards, and the major concern is due to exposure to spice dust. Exposure to spice dust has been reported in several literature and is known to cause allergic reaction, effect on respiratory system, asthma, irritation, sneezing, coughing, running nose, etc. and complaints as high as 49% were reported (Chan et al. 1990; Noor et al. 2000). The workers in the grinding section namely the mill operators, load carrying workers, and cleaners were the major affected due to the indoor dust. Skin burning was experienced by almost all the workers (90.62%) while grinding chilly, cough and sneezing was another major contributor to the health effects (84.37%) of the workers (see Table 3). Due to excessive noise about 59.37% workers reported headache and 65.62% of workers faced the problem of itching and irritating eyes. Only 15.62% workers reported nausea, and 43.75% workers had problem of watery nose.

3.3 Excessive Noise

Several studies are reported in literature highlighting the ill effects of excessive industrial noise. Generally in unorganized sector the noise levels are usually high, as they lack any noise control measures (Qutubuddin et al. 2013). Exposure to high levels of noise may lead to noise induced hearing loss (NIHL) (Olusanya et al. 2011). It is reported in a study (Olusanya et al. 2011) that more than 67% workers complained about NIHL in spice grinding mills in Nigeria. The noise levels were measured using a sound level meter LUTRON SL-4023SD. The noise measurements in the plant showed readings of 85.9 dB(A) to 95.3 dB(A) taken at different locations. The average noise levels in the grinding mills are above the permissible limits of 90 dbA, as per OSHA recommendations for 8 h work.

3.4 Use of Personnel Protection Equipment (PPEs)

Apart from engineering controls and administrative controls, personnel protective equipment is another means for controlling hazardous exposures (Babel and Rajvanshi 2013; Jagadish et al. 2018). Another study by Vinberg (2020) conducted on clothing practices and use of PPEs in spice grinding stressed the need to generate awareness for the use of PPEs to save themselves by different physical conditions.

The information gathered through questionnaire and direct observation included the use of PPEs in the spice grinding mills. Table 4 shows the usage of PPEs among the workers. None of the workers in the drying, grinding, or packaging were using certified masks. About 72% workers covered their faces with a cloth in grinding section while 55% workers covered their faces in drying area. Majority of women covering faces were women. Even hand gloves or safety shoes were not provided by the management. Few workers were seen wearing slippers/chappal (33% in drying and 38% in grinding). As the work in drying area was in open sky under sun, 66% workers covered their head with a cap/cloth, and 44% covered their head in grinding mill to protect against spice dust. Similar results were obtained by Qutubuddin et al. (2013a, b), Vinberg (2020), Nikhilkumar et al. (2020), Babel and Rajvanshi (2013), Chan et al. (1990), Noor et al. (2000) in studies conducted on spices grinding and other occupations in SSIs. The worker is seen bare-footed without any gloves, eye, or ear protection working in the grinding mill (see Fig. 3a). The worker is filling the sacs with turmeric powder from the baskets placed beneath the machine, without any PPEs, except a piece of cloth wrapped around face. In Fig. 3b, the worker is filling, weighing, and sealing small packets with chili powder, without any protective equipment.

The workers adapt various awkward postures while performing different activities in drying chili in open yard (see Fig. 3c, d). The chilies are spread in the open yard for drying under the sun, and a hand tool is used for spreading and collecting the chili, a hand scoop is used for filling the chili in empty baskets, the filled basket with chili is being lifted by the workers, and the women carry the chili baskets to the grinding mill adapting various postures.

Table 4 Use of personnel protective equipment by grinding mill workers

Type of PPE	Drying (n = 9)	Grinding (n = 18)	Packaging (n = 5)
Certified dust masks	No	No	No
Cloth/Towel to cover face	Yes (55.55%)	Yes (72.22%)	No
Ear plug/Ear Muff	No	No	No
Hand gloves	No	No	No
Safety shoes	No	No	No
Slipper/Chappal	Yes (33.33%)	Yes (38.88%)	No
Head Cap/cloth cover	Yes (66.66%)	Yes (44.44%)	No
Goggles/eye protection	No	No	No

Fig. 3 Awkward workers postures without use of PPEs

3.5 Low Cost Interventions-Workstation Design

A simple low cost ergonomic intervention was suggested and demonstrated to show the workers and the owners that how small changes with little investment can help in improving the working conditions, reduce the risks of MSDs, and increase productivity.

In the grinding mill, a low cost ergonomic solution was suggested and workstation redesigned where the posture of the machine operator is changed from standing to sitting with the available resources. Many studies indicate that the workstation design should be compatible with the anthropometry of the operators (Shikdar and Al-Hadhrami 2012).

Figure 4a—the operator stands on a bench to feed the dry chili into the hopper of the machine. The dry chili is brought from the open yard by material handling workers and kept at a height (on a make shift barrel) so that the operator can pick the baskets easily. The weight of the dry chili basket is 7–8 kg, and the coarse powder weight during second milling is 8–10 kg. The chili is fed slowly into the hopper continuously, and the activity is repetitive throughout the shift. The movement involves bending, twisting, and turning, stretching the arms and sometimes working above the shoulders.

Figure 4b—To overcome the drawbacks, a temporary arrangement of the workplace with the available materials around is demonstrated to the operators. The operator is made to sit at a proper height from where the chili baskets can be handled and fed into the hopper of the machine. The change in workstation design avoids the extreme conditions on the work posture and the operators comfort level is increased, without much bending, turning, and working above shoulders. Figure 4c—dimensions of the changes to be made in the workstation are measured for improvements in design. Figure 4d—An improved workstation design is suggested as shown. A high heighted stool with a small back support is designed for the operator to sit and perform the activities. The proposed changes are made by designing workstation and human manikin in CATIA software (Manzoor Hussain et al. 2019).

Both the existing working posture and the changed working posture are analyzed using Rapid Upper Limb Assessment (RULA) method (Nikhilkumar et al. 2020; McAtamney and Nigel Corlett 1993). The existing posture scored '7' on the RULA

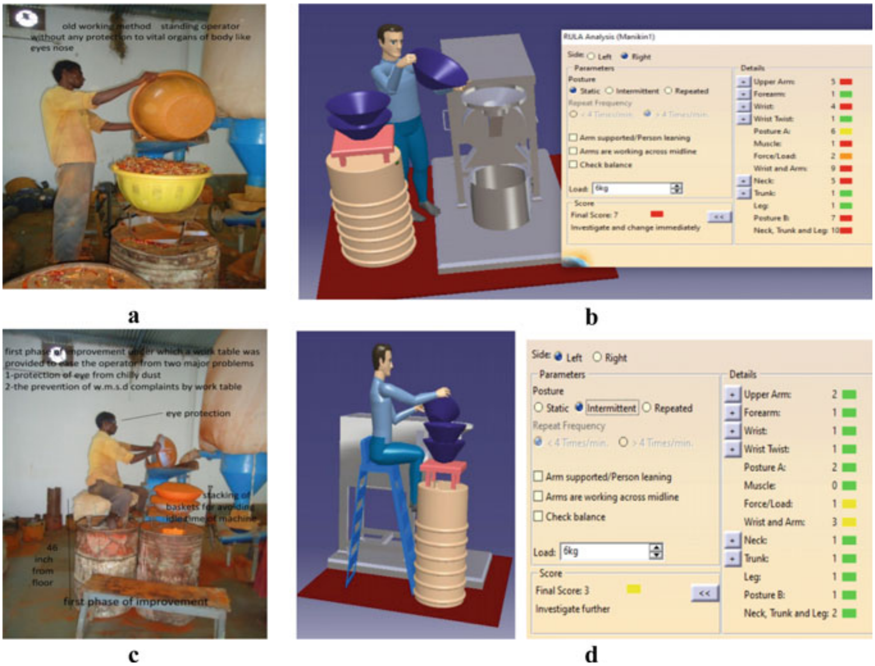

Fig. 4 Low cost ergonomic improvement on workers postures reduces risk of MSDs

score sheet suggesting further investigation and change in posture immediately to avoid further risks. The posture of the operator in the improvement suggested was also analyzed by RULA method. The score obtained was ‘3’ on RULA score sheet, indicating low risk and a change may be required in future. Further the worker was provided with a mask, goggle, gloves, ear plug, and shoes and asked to work. The change affected an increase in worker comfort and reduced risks of MSDs. This temporary change in the workplace was demonstrated to the owners and some workers voluntarily took part in this study. The changes were made with the locally available materials without any investments. The change is posture of the workers from standing to sitting increased the feeding rate to the grinding mill and an overall increase in productivity by 12 percent. The benefits of using PPEs and its awareness were demonstrated.

3.6 Low Cost Interventions—Use of Trolley for Material Handling

Another simple ergonomic solution was demonstrated which reduced risks of MSDs associated with manual handling. The earlier method practiced by the workers was

Fig. 5 Postures adapted by workers (**a**) and (**b**), ergonomic intervention (**c**) and (**d**)

fill to the basket with turmeric, lift a load of about 10–12 kg, and carry the basket to the turmeric mill located at a distance of 15 m (see Fig. 5a, b). The weight of each basket is about 10–12 kg. The work consists of filling the basket with turmeric, lifting, and carrying by adapting various awkward postures. After detailed observation, it was recommended to change the material handling method.

A hand trolley was purchased, and the trolley was brought closer to the point of operation and an empty basket was kept on the trolley (see Fig. 5c, d). The workers were asked to fill the basket directly which was kept on the trolley, thus the work element of lifting the load and carrying manually was totally eliminated. Along with it the various awkward postures like bending, twisting, lifting load, etc. were considerably reduced. Thus resulting in reduction of MSD risks due to manual handling and the time taken for material handling.

4 Conclusion

The present study was carried out to find out the OHS and ergonomic concerns in spice grinding mills, through a survey, questionnaire and observation and measurements. Preliminary study indicated prevalence of discomfort in the body parts, mostly in the upper limbs and eyes and skin. The work environment poses a risk to the workers' health due to air borne spice dust (Chan et al. 1990; Noor et al. 2000), excessive noise (Olusanya et al. 2011), awkward postures (Qutubuddin et al. 2013a, b; Nikhilkumar et al. 2020), and negligible use of PPEs (Jagadish et al. 2018). The work station at the grinding mill was redesigned by demonstrating with low cost interventions. The changed workstation improved the workers posture (Shikdar and Al-Hadhrami 2012), and RULA analysis indicated a low risk score. Another low cost ergonomic intervention was demonstrated at the drying place, and the work procedure was changed recommending the use of a hand trolley for material handling. The changes made reduced manual handling of repetitive workload, and the postures adapted the risks of developing MSDs. The use of trolley also saved the time to carry per load and productivity increased by about 10 percent.

Airborne spice dust is associated with various diseases like allergy, asthma, and other respiratory ailments due to inhalation of spice dust in the workplace (Babel and Rajvanshi 2013; Chan et al. 1990; Ajeel and Al-Yassen 2007). It is recommended to use NIOSH approved respirators while grinding spices. Proper eye protection, ear protection, and use of gloves to avoid direct skin contact with skin is highly recommended. Ergonomic interventions with little or no investment were demonstrated which resulted in reduced worker complaints and increase in productivity. Further improvements can be achieved if the owners implemented the given ergonomic solutions and encourage use of PPEs. Periodic checks are recommended every three months to review the results of proposed changes and take corrective measures.

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Chapter 35
Occupational Stress Factors Associated with Quality of Life Among Government and Non-government Bus Drivers of Kolkata City

Samrat Dev and Somnth Gangopadhyay

1 Introduction

The job of public bus drivers is considered as one of the most stressful and unhealthy occupations of modern society (Evans and Carrere 1999). Bus driving is mainly a stressful job, which needs high mental or psychological demands. Like many other passenger transport industries, the safety of travellers and other road users is of prime importance for bus drivers. The main task of bus drivers is to drive safely and must successfully balance the competing demands of safety, customer-focused service, and company operating regulations and maintain a timely schedule (Whitelegge 1995). Several studies have suggested that MSD occur due to ergonomic risk factors such as awkward postural stress, repeated and forceful motions, prolonged working time in constant sitting and long-term exposure to whole body vibration as well as occupational factors, such as high quantitative job demands, monotonous job pattern, low coworker support, low earning, psychological job demands, and job dissatisfaction (Leinonen et al. 2005; Rugulies and Krause 2008; Azam et al. 2019; Desouky and Allam 2017). Literature over fast few decades on operating public transit vehicles shows that as compared to workers in other occupations, bus drivers are more likely to experience different types of disorders, sometimes which affect them extremely (Kompier 1996). The intra-city short distance bus drivers of Kolkata cover distances through highly congested roads and have to remain alert all the time. This in turn poses an additional hassle for the drivers. Moreover they often drive buses fully loaded with commuters, which is also another hazard in terms of deviation of concentration. On consideration of the given nature of their work and their potential for psychological problems, these bus drivers represent a particularly

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interesting group for study. The occupational stress was examined to identify any correlation with various factors like older age, lower income, and higher education level and prove that related to poorer quality of life (Yuhua et al. 2019). The impact of working environment, job stress or strain, fatigue, psychological and social support, or relationship link with risky driving (Sergio et al. 2017).

2 Methodology

2.1 Non-government Buses of Kolkata and Bus Drivers

Among the different types of buses that ply in the city of Calcutta, the non-government buses are significant ones. Since these buses constitute the backbone of the local transportation for the common man in the city, so a large number of them run throughout the city in various routes.

The drivers driving in different routes of Kolkata and their income depend upon the number of passengers, that is, on commission basis.

The regular work schedule of these drivers represents an alarming picture. They work continuously even up to 16–18 h each day, and there is no system of weekly off for them. They carry out their job as long as their body permits, and the duration may vary from 15 to 20 days at a stretch followed by a break of 4–5 days. They begin their work right from the early morning till almost midnight. They undertake 5–6-trips each day where one trip means to and fro journey i.e., starting from the depot to the final destination and returning to the depot.

2.2 Government Buses of Kolkata and Bus Drivers

However there is a distinct difference in the mode of operation of government buses. Government bus includes one driver and one conductor, and there is only one gate for entry and exit of passengers. They work in shifts-either morning, day or night, average duration 8 h per shift but most of the time extended up to 10 h. They undertake 2–3 trips each day where one trip means to and fro journey i.e., starting from the depot to the final destination and return to the depot. They also get fixed monthly salary for their job, which is paid by the government, and they are entitled to periodic increments as per government rules. Moreover they also enjoy regular leave benefits, get ESI facilities, annual incentives, and can also alter their shifts in case of emergency or otherwise health reasons.

All drivers are more stressed out while passing through congested roads and junction points. They have to remain very careful when people are either getting down or alighting the bus particularly for children, women, and aged people. Thus in spite of all odds, they continue their job relentlessly for hours maintaining constrained sitting postures. All these make their work extremely hectic and stressful.

2.3 Selection of Subjects

The cross sectional study was conducted among bus drivers working at a different Bus route of Kolkata city. For this study four bus routes each (non-government and government bus) was randomly selected. In the present investigation, 127 male bus drivers (non-government) and 125 male bus drivers (non-government) having more than one year of experience were enrolled in the study. From all the 254 bus drivers prior to the data collection informed consent was obtained from them and the study was approved by the Institutional Ethics committee. Permission was also obtained from the concerned authorities to conduct the study. Finally data was collected from 240 bus drivers as 12 drivers could not show further interest for the study. Thus average one full trip of the bus involves distance coverage of 36–60 km.

2.4 Measurement of Physical Parameters

The height and weight of the bus drivers were measured by an anthropometer (Martin's Anthropometer) and "Crown" weighing machine (Mfg. by Raymon Surgical Co.) respectively. The Body Surface Area (BSA) (Poskitt 2000) and Body Mass Index (BMI) (Cole et al. 2000; Astrand and Rodahl 1986) of all the subjects were also computed.

2.5 Questionnaire Study

A detailed study based on questionnaire was performed which consists of a series of objective-type questions with multiple-choice responses. The face-to-face interview was thought to be more reliable in obtaining accurate information from the bus drivers as they were from a wide range of backgrounds with different educational levels.

The questions regarding driving experience were in terms of years of driving and daily driving hours, surface, and environment of driving, style of driving.

2.6 Assessment of Occupational Stress

The assessment of psychological stress was carried out by Occupational Stress Index method (OSI) (Srivastava and Singh 1981). This questionnaire method consists of a scale having 46 items, each to be rated on the five-point scale. Out of 46 items 28 are true keyed and rest 18 are false keyed. The items relate to almost all relevant components of the job life that causes stress in some way or the other, such as role overload, role ambiguity, role conflict, powerlessness, low status, and strenuous working conditions. The following table provides guidelines to score the responses given to categories of item. The scores were divided into three categories i.e. high, moderate, and low following the principles of normal distribution.

2.7 Evaluation of Quality of Life

The quality of life was computed using the World Health Organization's "Quality of Life Questionnaire" [WHOQOL-BRIEF] (Wig et al. 2006). The WHOQOL-BRIEF contains a total of 26 questions. These 26 questions could derive four domain scores, viz., physical health, psychological domain, social relationship, and environment respectively. There were also two items that were examined separately: question 1 enquired about an individual's overall perception of quality of life and question 2 ascertained an individual's overall perception of his health. The four domain scores denoted an individual's perception of quality of life in each particular domain. Domain scores were scaled in a positive direction (i.e. higher scores denoting a higher quality of life). The mean score of items within each domain was used to calculate the domain score. Manual calculation of individual score was done as per the instruction in the questionnaire. Mean scores were then multiplied by 4 in order to make domain scores comparable with the scores used in the WHOQOL-100 Questionnaire. A standard method was used for converting raw scores to transformed scores. The first transformation method converted scores to a range of 4–20, comparable with the WHOQOL-100; the second transformation method converted domain scores to a 0–100 scale.

2.8 Statistical Analysis

The mean and standard deviation of the various physical and physiological parameters were calculated.

Student 't' test was performed to find out whether there is any significant difference between the physical and physiological parameter and also for quality of life questionnaire, occupational stress index (Das and Das 1993).

3 Result

Bus drivers who are suffering from occupational stress frequently report tension, mental overload, physical fatigue, mental fatigue, and sleeping problems. Bus drivers also have more frequent absences from work and of longer duration than workers in other occupations (Evans and Carrere 1999). The design of the driver's cabin and the environment inside due to noise and humid conditions also increase the stress of the drivers. In particular, the high population density in Kolkata city means additional stress for the drivers, who have to deal with many passengers getting on and off the buses, as well as monitoring the road situation and nearby pedestrians. All these job demands pose substantial physical as well as psychological stresses on the drivers. The analysis of the questionnaire of occupational stress index revealed that with advancing work experience, the drivers are incapable of adjusting their huge workload and become mentally fatigued whereas the less experienced ones seem to be somewhat accommodative and suffer less from mental agony. Job factors which contribute to developing stress in bus drivers are prolong work shift schedule, less rest break, irregular meal times, traffic congestion, constant visual, and mental alertness and bad condition of roads and awful behaviour from pedestrians and other vehicles on road.

After collecting the detailed questionnaire and successfully completing the physical assessment, it was analysed and compared between the two groups of bus drivers. Finally the information is tabulated. From the questionnaire it was found that the non-government bus drivers work 16–18 h daily and take rest for about 10–15 min between each trips. Bus drivers work for 20–22 days in a month at a stretch. The government bus drivers work 8–10 h daily and take rest for about 20–30 min between each trip. The number of working days was 24–25 days in a month with one day weekly off. The minimum year of experience of the non-government bus drivers was 1 year and maximum was 31 years. In case of the other group of drivers the minimum work experience was 2 years and 27 years was maximum.

It was observed from the results that the mean age of the non-government bus drivers was 35.8 years (±7.6); their mean height was 164.3 cm (±5.1) and mean weight was 54.6 kg (±7.6) (Table 1). The mean values of physical parameters like BSA and BMI were 1.61 m^2 and 19.17 kg/m^2 respectively which showed that all of them have a normal range of BSA and BMI.

From the results of the government bus drivers the mean age was 51.7 years (±9.7), their mean height was 163.2 cm (±5.0), and mean weight was 52.9 kg (±6.9). The mean values of physical parameters like BSA and BMI were 1.6 m^2 and 19.8 kg/m^2 respectively which showed that all of them have a normal range of BSA and BMI (Table 1).

Table 1 Demographic and workload profiles of bus drivers

	Non-government bus drivers (n = 110)			Government bus drivers (n = 110)			't' value
	Range	Mean	± SD	Range	Mean	± SD	
Age (years)	25–52	35.8	7.6	25–57	51.7	9.7	**13.3**[a]
Height (cm)	149–175	164.3	5.1	151–172.5	163.2	5.0	1.5[b]
Weight (kg)	43–78	54.6	7.6	45–73	52.9	6.9	1.7[b]
BSA (m^2)	1.47–1.86	1.6	0.1	1.44–1.92	1.6	0.1	0.6[b]
BMI (kg/m^2)	16.06–24.96	19.7	2.3	17.14–24.96	19.8	2.4	0.3[b]
Years of experience	1–31	25.8	8.5	2–27	11.1	6.9	**13.7**[a]
Duration of work per day (in hour)	16–18	16.7	0.9	8–10	9.0	0.9	**58.0**[a]
Number of trips per day	4–6	5.0	0.7	2–3	2.3	0.5	**31.6**[a]
Number of working days in a month	18–25	22.0	1.5	24–26	24.2	0.9	**12.4**[a]

[a]Significant, [b]Not Significant, Significant Level ($P < 0.05$)

3.1 Occupational Stress

From the study of the occupational stress index questionnaire it was shown that both the groups are suffering from occupational stress and that is due to their present occupation. Non-government bus drivers show higher stress in Powerlessness, Intrinsic Impoverishment, Low Status, Strenuous Working Condition, and Unprofitability. On the other hand government bus drivers show higher stress in Role overload, Under participation, Poor Peer relation, Intrinsic Impoverishment and Strenuous Working Condition (Table 2).

The detailed analysis of occupational stress survey shows that maximum numbers of bus drivers from both the experimental groups have high and moderate levels of occupational stress. Non-government bus drivers face maximum stress due to powerlessness, improvement, low status, strenuous working conditions, and unprofitability. On the other hand government bus drivers show higher stress in role overload, under participation, poor peer relation, intrinsic impoverishment and strenuous working conditions. Bus drivers have to cope up with the monotony of this job, and this monotony gradually decreases their interest, enthusiasm, and energy to perform at their best. Lack of motivation, reward from authority adds to this depressing situation. Employees often complain of losing self-identity. Psychosocial factors such as job satisfaction, ability to handle stress, and psychological status are also important factors to consider in occupational health (Table 2) (Fuerestein et al. 2004; Devereux et al. 1999).

Table 2 Analysis of occupational stress index of bus drivers

S. No	Question	Non-government bus (n = 110)			Government bus (n = 110)			't' value	Remarks
		Level of occupational stress	Mean	± SD	Level of occupational stress	Mean	± SD		
1	Role overload	Moderate	18.8	2.2	High	26.1	2.3	24.1	**S**
2	Role ambiguity	Moderate	10.9	0.8	Low	6.9	1.2	29.1	**S**
3	Role conflict	Low	9.8	2.1	Moderate	15.7	0.9	27.1	**S**
4	Unreasonable group and political pressure	Moderate	11.8	1.4	Moderate	11.9	1.4	0.5	NS
5	Responsibility of person	Low	5.6	1.3	Low	5.7	1.1	0.6	NS
6	Underparticipation	Moderate	10.8	0.8	High	16.1	2.1	24.7	**S**
7	Powerlessness	Low	13.2	1.1	Moderate	9.4	0.9	28.1	**S**
8	Poor peer relation	Low	6.2	1.2	High	17.1	1.7	54.9	**S**
9	Intrinsic impoverishment	High	16.3	1.8	High	17.9	1.9	6.4	**S**
10	Low status	High	13.5	1.1	Moderate	9.4	1.4	24.2	**S**
11	Strenuous working condition	High	16.2	1.9	High	16.5	2.1	1.1	NS
12	Unprofitability	High	8.9	0.9	Moderate	6.3	0.7	23.9	**S**

S—Significant, NS—Not Significant, Significant Level ($P < 0.05$)

3.2 Quality of Life

The mean scores in the four domains of Quality of Life (QoL) of the bus drivers were obtained by using WHOQOL-BRIEF questionnaire. From the analysis of the questionnaire it was found that social relationship domain shows highest score, followed by environmental domain, psychological domain and the physical domain, in descending order in both the type of bus drivers. Physical health domain measures the effect of health on the daily activities for living, dependence on medicinal substances and medical aids, energy and fatigue, mobility, pain and stress, sleep and rest, and work capacity. Psychological domain assesses subjects' own thoughts about their bodily image and appearance, negative feelings, positive feelings, self-esteem, spirituality/religion/personal beliefs, thinking, learning, memory and concentration facets. The social relationship domain evaluates personal relationships, social support, and sexual activity facets. Environmental domain measures influence factors like financial resources, freedom, physical safety and security, health and social care: accessibility and quality, home environment, opportunities for acquiring new information and skills, participation in and opportunities for recreation/leisure activities, physical environment (pollution/noise/traffic/climate) transport. In this study, the highest score was observed to be in the social relationship domain and indicated the volunteers' healthier involvement in personal relationships, social support, and sexual activity facets. Lowest score of the physical domain might be due to long working hours of these volunteers, which cause lack of proper rest and leisure time. Statistical analysis among the group shows that physical and environmental domains have no significant difference but psychological and social relationships have significant differences.

From the Quality of life score of both the groups of drivers (Table 3) it is evident that domain 'social relationship' scored the maximum followed by 'environment', 'psychological' and 'physical' domain respectively. The physical stress was due to long working time with adequate rest periods and also by the ergonomic limitation of workstation hazards, this could be the reason for the 'physical domain score to lag

Table 3 Mean (±SD) of domains of quality of life amongst the bus drivers

Parameters	Non-government bus drivers (n = 110)	Government bus drivers (n = 110)	't' value	Remarks
Domain I (Physical)	35.7 ± 7.7	38.2 ± 11.9	1.9	**NS**
Domain II (Psychological)	54.9 ± 15.9	45.7 ± 13.3	4.7	**S**
Domain III (Social Relationships)	70.1 ± 10.7	76.9 ± 7.1	5.6	**S**
Domain IV (Environmental)	59.1 ± 13.2	61.1 ± 9.8	1.3	NS

S—Significant, NS—Not Significant, Significant Level ($P < 0.05$)

behind all other domains. The statistical analysis between the physical and environmental domain of both the groups shows no significant result, which revealed that they belong to poor physical and environmental domains. On the other hand psychological and social relationship domain shows significant results which exposed that non-government bus drivers have more psychological stress as compared to government bus drivers. One of the items in the questionnaire also enquired about their leisure time and whether it was enjoyable (data not provided in the table). Most of the respondents (79.4%) informed that after the long day at work they are hardly left with any energy except for cooking, eating, and going to bed. Many of them find it extremely difficult to carry on some task involving constrained postures. Sometimes they are unable to take care of their personal needs. Most often they avoid social gatherings, going to relative places and other outdoor recreational activities like watching movies and shopping with their families, which again shows a lot of discomfort. Occupational stress also believed to play a significant role in causing cardiovascular, gastrointestinal disorders and musculoskeletal disorders (Bartone 1989). Sometimes drivers are also stressed due to traffic congestion, bad road condition, behaviours of the passengers and other vehicles on the road (Sergio et al. 2018). The work stress and driving crashes support the fact that workplace stress negatively affects the performance of several activities, such as driving and decreases the performance (Francisco et al. 2000).

4 Conclusion

The results of this study show that, overall, a high percentage of the bus drivers of Kolkata city are highly stressed because of their stressful working environment. Bus drivers are not happy with their prolonged irregular and erratic working hours and duration, relation with authorities, less income, social status, monotones job pattern, poor and award posture and inadequate diet. Furthermore, the significant relationships found between levels of occupational stress, physical exhaustion and traffic crashes suffered by drivers support the theory that harmful work-related factors have a direct impact on driving performance and health problems. Measures should be taken not only by bus authorities but also by the government and commuters to improve the conditions of roads, traffic, driver's seat and bus cabin design and passengers' behaviour towards transport workers to reduce factors causing stress and quitting their job and improve safety, comfort and overall increasing productivity.

Limitation

Sample size was small and number of bus drivers from various bus depots should be included in the study.

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Conflict of Interest The authors report no conflict of interest.

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Chapter 36
Performance Evaluation of Knapsack Type Roto Paddy Weeder

P. U. Shahare, Ketan B. Phalphale, V. V. Aware, and Sachin V. Pathak

1 Introduction

RICE (Oryza sativa L.) is a plant belonging to the family of grasses, Gramineae (Poaceae). In India, rice is the most important and extensively grown food crop, occupying about 44.8 M ha of land (Nagre 2018) with production of 110 million tonnes (Anonymous 2017a). In Maharashtra, rice is cultivated over an area of 15.03 lakh hectares with an annual production of about 25.93 lakh MT and productivity recorded was 1725 kg/ha (Anonymous 2017b).

Weeds cause most yield loss within the first 20–50 days after crop establishment (Anonymous 2015). Delay and negligence in weeding operation affect the crop yield and the loss in crop yields due to weeds in upland crops varying from 40 to 60% and in many cases cause complete crop failure (Singh 1988). The different methods of weed control are mechanical, chemical, biological and manual methods. Out of these four methods, mechanical weeding either by hand tools or mechanical weeders is most effective in both dry land and wet land (Nag and Dutt 1979; Gite and Yadav 1985, 1990). In Konkan region, due to heavy rainfall unwanted weeds grow fast in paddy field, viz. *Echinochloa crus-galli, Echinochloa colonum L., Panicum repense L., Eleusine indica L.* and *Cynodondactylon L.* etc. The traditional methods of weed control like hand weeding and manually operated weeders prove to be time consuming and cumbersome in operation with less efficiency. The efficiency of the work is often lowered by hot and humid weather conditions during the rainy seasons. Manual operated weeder implies the more stress on operators because of its operation (to and fro movement) of the weeder. Farmers are very much familiar with back mounted sprayer (knapsack). Considering its portability and easy handling, efforts were made to develop knapsack type power weeder. This light weight engine operated machine and is capable of reducing the drudgery to a large extent and

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increasing speed of work. As field size of Konkan region is very small, light weight power weeder would be suitable for rice crop of Konkan region. The paddy weeder is operated in standing water in the field and it is mounted on back of worker, its ergonomic evaluation was done in order to access its workload.

2 Materials and Methods

Looking into the requirement of smaller size, light weight and portability, knapsack type (back mounted) was designed. In Konkan region paddy is planted at the spacing of 25 × 10 cm or 25 × 15 cm.

2.1 Development Procedure

The developed paddy weeder consists of engine, flexible and rigid shaft, worm gear box, rotor with blade, frame, handle, rotor shaft, throttle lever, mud flap and backpack frame. A petrol engine of 1.9 hp @ 6500 rpm (make-Kisan Kraft, 2 Stroke) was selected as prime mover for the developed weeder. The reduction gear box (ratio—32.5:1) was used to reduce the speed to 200 rpm. The same speed was given to rotor of the machine. The handle and throttle lever were provided on the rigid shaft to control and proper positioning the weeder during working. The power operated knapsack type roto paddy weeder was developed with three types of rotor, viz. rotor with 4-L shape blades, rotor with 6-L shape blades and rotor with serrated-flat blades. Total working width of the weeder was 300 mm and rotor shaft length of 500 mm. To avoid throwing of mud and stones toward operator a mud flap is provided covering the upper and rear side of the blades of the rotary cutting units. The performance of the developed weeder for all the three rotors studied independently.

The rotor with 4-L shape blades were made of MS flat 25 × 2 mm size, length of 220 mm. The MS flat was bent from one end to form ‘L’ shape to satisfy the cutting length of 75 mm and fixed to rotary flange of 130 mm diameter by using nut and bolt of diameter 7 mm. The thickness of flange was 6 mm. The flange was connected to the rotating shaft with the help of nut and bolts. In order to take into account fluctuating load during the operation, diameter of the rotor shaft was selected as 18 mm, so as to suit gear box. The length of shaft was taken as 500 mm to suit row to row spacing of rice plant. Total of 4 blades were connected in orthogonally opposite direction and on the flange for 4-L shape, with cutting width of 75 mm. The rotor with 6-L shape blade was made similarly as 4-L shape blades but it differs by number of blades. Total 6 blades were connected in orthogonally opposite direction and on the flange for 6-L shape, with cutting width of 75 mm. The rotor with serrated-flat blades (2 Nos.) was made from MS sheet of 200 × 200 mm size, length of 150 mm and 3 mm thick. The MS sheet was cut in circular disc of 200 mm diameter (2 Nos.). Two discs attached by a pipe of 130 mm length, 18 mm internal diameter and 25 mm outer

Fig. 1 Power operated knapsack type roto paddy weeder

diameter at their center. The serrated and flat blades were made of MS plate 45 × 2 mm size and length of 150 mm. After fabrication of rotor, these serrated-flat blade rotors then fitted over output shaft of gear box at both sides with the help of nut and bolts. The rotor shaft length was kept as 500 mm. The newly developed paddy weeder is shown in Fig. 1.

The developed weeder was tested in the field and the parameters, viz. weeding efficiency, plant damage, effective field capacity and fuel consumption.

2.2 Ergonomic Evaluation Methodology for Power Operated Knapsack Type Roto Paddy Weeder

Along with the field performance the power operated knapsack type roto paddy weeder was also evaluated ergonomically to access the drudgery involved in weeding operation. The six male subjects previously calibrated in laboratory (Fig. 2) were selected for the study. They were given all the instructions related to the test. Accordingly, the trials were conducted. Each subject was initially given sufficient rest to bring their heart rate to normal. Thereon the trial was started. The subject was made to operate the weeder until he felt exhausted. The heart rate data of the first resting time and also of the operation time were recorded in beats per minute (bpm) using Polar RS 400$^{\text{Tm}}$ portable heart rate monitor. The recorded heart rate values were downloaded to the computer. The average heart rate from 6 min up to the completion time was computed for the further calculation and analysis. The same procedure was adapted to all the selected subjects. Following were the parameters used to determine the physiological cost involved in operating power operated knapsack type rob paddy weeder.

Fig. 2 Calibration of subject for ergonomic evaluation

1. Heart rate (HR)
2. Oxygen consumption rate (OCR)
3. Energy expenditure rate (EER)
4. Acceptable work load (AWL)
5. Limit of continuous performance (LCP)
6. Work rest cycle
7. Overall discomfort rating (ODR)
8. Body part discomfort score (BPDs).

(1) *Heart rate (HR)*:

Measuring heart rate is one of the most useful ways or assessing the workload because it can be done very conveniently. Thus heart rate of the subjects was recorded during the operation by using the heart rate monitor. All the functions of the heart rate monitor were set as per instructions given in the manual. The subjects were given sufficient rest before starting the trial to make the heart rate normal. From the downloaded data, the values of heart rate (HR) were taken for calculation of working HR as the physiological response of the subjects.

(2) *Oxygen consumption rate (OCR)*:

The oxygen consumption of subjects during the operation was carried by indirect assessment. From the mean values of heart rate determined during the experiment a graph representing linear relationship between heart rate and Oxygen consumption rate was plotted.

(3) *Energy expenditure rate (EER)*:

The oxygen consumption rate corresponding to heart rate of the male subjects during operation with power operated knapsack type roto paddy weeder were predicted from the calibration chart of each individual subject. The energy expenditure during the experiments was computed by multiplying the oxygen consumption values with the calorific value of oxygen which is 20.88 kJ (Nag and Dutt 1979).

$$\text{EER(kJ/min)} = \text{OCR (l/min)} \times 20.88 \tag{1}$$

The values of HR, OCR and EER for all the subjects were averaged to get the mean values for all the selected subjects. On the basis of the values of EER in kJ/min, the grade of work was decided.

(4) *Acceptable work load (AWL)*:

Work load can be expressed as percentage of the individual's maximal aerobic power (VO_2 max), i.e. how much of the individual's maximal aerobic power has to be taxed in order to accomplish the work in question. The acceptable workload for Indian workers was the work consuming *35%* of the VO_2 max (Saha et al. 1979). To ascertain whether the operations selected for the trails were within the acceptable workload, the oxygen uptake in terms of VO_2 max (%) for each treatment was computed.

(5) *Limit of continuous performance (LCP):*

The extent to which a person may increase his work rate depends in part on how much he can increase his heart rate from resting level to his maximum level, because the increase in heart rate plays a major role in increasing the cardiac output from rest to maximal work. To have a meaningful comparison of physiological response, the difference in the working and resting heart rate, i.e. (ΔHR) and was compared with the acceptable work pulse values of 40 bpm.

(6) *Work rest cycle*:

This is the actual rest that must be taken by a subject after he has undergone some strenuous farming operation. At extreme workload a person could work only for few seconds. In order to get a better performance from the subject he must be given ample time of rest after carrying any operation. The acceptable workload for Indian workers was the work consuming 35% of VO_2 max. Better performance can be expected from workers only when proper attention is given for the work rest schedule in different operation. The actual rest time taken for each subjects while weeding was found from the heart rate response curves of subjects. To determine the rest pause after the weeding operation the following formula was used (Murrel 1965).

$$R = T(K - S)/(K - 1.5) \tag{2}$$

where

- R Rest required, min
- T Total working time, min
- K Average kcal per mi of work
- S Average kcal per mi adopted as standard

(7) *Overall discomfort rating (ODR)*:

Overall discomfort rating is the method of accessing the overall body discomfort. A 10-point psychophysical rating scale marked 0 to 10 digits (0—no discomfort, 10—extreme discomforts) was used to assess the overall discomfort rating (Corlet and Bishop 1976). The numbers on the scale showed the level of discomfort experienced by subject during the experiment. At the end of each experiment, each subject was asked to indicate their overall discomfort rating on this scale. The overall discomfort ratings given by each subjects were added and averaged.

(8) *Body part discomfort score (BPDS)*:

To measure body part discomfort score the technique of dividing subjects' body in 27 regions was used (Corlet and Bishop 1976). After completion of the work the subjects were asked to point out the painful regions which caused discomfort during the operation. The body part discomfort score of each subject was calculated by multiplying number of body parts corresponding to each category. The body discomfort score of all the subjects were lastly added and the average value gave the discomfort score.

(9) *Determination of physiological cost and drudgery*:

The ergonomic evaluation of the developed power weeder was carried using male subjects based on the physiological parameters like working heart rate, overall discomfort rate and body part discomfort score. The experiment was conducted in paddy field of department of Agronomy. DBSKKV, Dapoli during 2018–19. The information about experiment was given subject to ensure their full cooperation. All the subjects were equally trained in the paddy weeding. Heart rate monitor was used to record heart rate.

3 Results and Discussion

The rotor with 4-L shape blades were attached to the weeder and its performance was tested in the field. The weeder with rotor having 4-L shape blade was tested for weeding efficiency, plant damage, field capacity, field efficiency and fuel consumption at 30 days after transplanting. In similar manner other two rotors (rotor with 6-L shape blade and rotor with serrated-flat blades) were also tested at Repoli Farm and Agronomy Farm of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, during summer 2019 (Fig. 3). Rectangular field was selected for each test.

Fig. 3 Field operation of power operated knapsack type roto paddy weeder

3.1 Comparative Field Performance of Developed Paddy Weeder with Different Rotors

(1) Weeding efficiency:

At 30 days after transplant the rotor with serrated-flat blades resulted into highest weeding efficiency of 88.24% whereas rotor having 4-L shape blades and 6-L shape blades has given highest weeding efficiency as 77.92% and 81.84%, respectively. The rotors of serrated-flat blade resulted higher weeding efficiency of 11.69% and 7.25% over 4-L shape blade and 6-L shape blade (Table 1).

(2) Plant damage:

The rotor with 4-L shape blades resulted into minimum plant damage of 1.23% at 30 DAT, whereas rotor with 6-L shape blades and serrated-flat blades gave plant damage as 1.43 and 1.59% for same days. It was found that the rotor with 4-L shape

Table.1 Weeding efficiency (%) of developed weeder using different rotors

Type of rotor	Plot No. 1			Plot No. 2			Plot No. 3			Average
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	
Rotor with 4-L shape blade	78.03	75.70	75.68	85.32	76.54	78.86	73.91	79.67	77.55	77.92
Rotor with 6-L shape blade	83.33	85.71	82.70	80.00	82.32	78.53	83.90	76.06	84.00	81.84
Rotor with serrated-flat blade	87.50	87.64	86.84	87.77	90.50	85.71	87.50	91.94	88.72	88.24

Note L_1 to L_3—Locations selected randomly within the plot

Table.2 Plant damage (%) by developed weeder using different rotors

Type of rotor	Plot No. 1			Plot No. 2			Plot No. 3			Average
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	
Rotor with 4-L shape blade	0.00	1.45	3.28	0.70	2.00	0.83	0.00	2.84	0.00	1.23
Rotor with 6-L shape blade	2.03	1.48	1.41	0.00	2.14	3.79	1.39	0.68	0.00	1.43
Rotor with serrated-flat blade	1.41	0.00	2.86	2.94	1.39	1.43	1.45	0.00	2.82	1.59

Note L_1 to L_3—Locations selected randomly within the plot

blade has resulted into 22.64% less plant damage over rotor with serrated-flat blades and 10.26% over rotor with 6-L shape blades (Table 2). The plant damage by all the rotors while weeding was very less and it is less than 2% though the comparison figures look to be very high.

(3) Effective field capacity:

The maximum field capacity was found with rotor having 4-L shape blades as 0.034 ha/h. While the effective field capacity of weeder with rotor with 6-L shape blades and rotor with serrated-flat blades was found to be 0.033 ha/h and 0.031 ha/h, respectively. The rotor with 4-L shape blades resulted into 2.94 and 5.88% higher effective capacity (field coverage) over rotor with 6-L shape blades rotor with serrated-flat blades, respectively (Table 3). It indicated that the field capacity of weeder with rotor of 4-L shape blade has shown slightly higher field capacity for weeding operation.

(4) Fuel consumption:

It was found that the weeder with rotor having 4-L shape blade has shown minimum fuel consumption for weeding operation. It resulted into minimum fuel consumption of 0.630 l/h whereas rotor with 6-L shape blades and rotor with serrated-flat blades has given fuel consumption of 0.689 l/h and 0.772 l/h, respectively, and found to be 10.79% and 22.59% less over 6-L shape blade and serrated-flat blade, respectively (Table 4).

Though the weeder with rotor having serrated-flat blades has shown some higher fuel consumption, it showed less field capacity but better weeding efficiency of 11.69% and 7.25% % more than rotor with 4-L shape blade and rotor with 6-L shape

Table.3 Effective field capacity (ha/h) of developed weeder using different rotors

Type of rotor	Plot No. 1	Plot No. 2	Plot No. 3	Average
Rotor with 4-L shape blade	0.035	0.033	0.034	0.034
Rotor with 6-L shape blade	0.033	0.031	0.034	0.033
Rotor with serrated- flat blade	0.029	0.032	0.031	0.031

Table.4 Fuel consumption (l/h) of developed weeder using different rotors

Type of rotor	Plot No. 1	Plot No. 2	Plot No. 3	Average
Rotor with 4-L shape blade	0.640	0.600	0.650	0.630
Rotor with 6-L shape blade	0.693	0.720	0.681	0.698
Rotor with serrated-flat blade	0.776	0.763	0.777	0.772

blade, respectively. The plant damage while weeding using all the three rotors for rice crop is very less and within the acceptable limit. Hence, though the coverage of machine with rotor of 4-L shape blade and 6-L shape blade is higher but on weeding point of view, as a major function of power weeder, the rotor with serrated-flat blades is found to be better over rotors having 4-L shape blades and 6-L shape blades.

3.2 Ergonomic Evaluation of Power Operated Knapsack Type Roto Paddy Weeder

(1) *Maximum aerobic capacity (VO_2 max) of subjects:*

The maximum heart rate (HR max) of selected subjects was calculated using equation. The maximum aerobic capacity was predicted. It was the maximum uptake of oxygen at maximum heart rate. The maximum heart rate and maximum aerobic capacity were calculated. The mean value of HR max and VO_2 max are furnished are given in Table 5.

The average age of the selected subjects was 32 (±4.68) years. The mean stature value of six subjects was 161 (±5.22) cm. Maximum heart rate of the group was in the range of 181–192 bpm with corresponding maximum aerobic capacity in the range of 2.36–3.08 1/min. The mean HR max and mean VO_2 value for the male subjects were 188 (±4.68) bpm and 2.64 (±0.241/min), respectively.

(2) *Working heart rate (WHR), oxygen consumption rate (OCR) and energy expenditure rate*:

Table.5 Subjects' details and mean value of maximum heart and oxygen consumption rate

Sr. No	Particulars	Results
1	Number of subjects	6
2	Mean age, years	32 (±4.68)
3	Mean stature, cm	161 (±5.22)
4	Mean weight, kg	67 (±9.50)
5	Range of HR max, bpm	181–192
6	Mean HR max, bpm	188 (±4.68)
7	Range of VO_2 max, l/min	2.36–3.08
8	Mean VO_2 max	2.64 (±0.24)

Table.6 Physiological parameters of the subjects

Subject code	Resting HR (bpm)	Working HR (bpm)	Δ HR	LCP, 40 bpm	Working OCR, (l/min)	EER (kJ/min)	Energy grade of work
SM	86.17	127.87	40.60	>LCP	1.68	35.08	Very heavy
RN	81.17	129.45	48.29	>LCP	1.24	25.89	Heavy
SS	77.17	118.36	41.20	>LCP	1.07	22.34	Heavy
AA	80.00	111.18	31.18	<LCP	1.03	21.51	Moderately heavy
MS	76.83	128.27	51.44	>LCP	1.33	27.77	Heavy
PB	76.83	120.18	43.35	>LCP	1.32	27.56	Heavy
Mean	79.78	122.45	42.68		1.28	26.69	Heavy
SD	(±3.84)	(±7.14)	(±7.03)		(±0.23)	(±4.87)	

During the test all the subjects were considered individually to check their performance in operating the power weeder. The heart rate response was recorded using heart rate monitor and by following the proper procedure. The physiological parameters measured during the operation of developed power weeder are given in Table 6.

As per the results obtained from the ergonomic tests of the power operated knapsack type roto paddy weeder, average WHR values of the subjects ranged between 111.8 and 129.45 bpm with mean value 122.45 (±7.14) bpm. The work pulse (ΔHR) was in the range of 31.18–51.44 with average as 42.68 (±7.03) bpm. It was observed that Δ HR values for some of subjects went above limit of continuous performance value, i.e. above 40 bpm, which indicated the necessity of rest pause to the operators.

From the results, it was also observed that average working OCR of the subjects were between 1.03 to 1.68 1/min, with mean 1.28 (±0.23) 1/min. The energy expenditure rate for all subjects was calculated using equation. It varied from 21.51 to 35.08 kJ/min with 26.69 (±4.87) kJ/min as mean EER. Thus, the energy grade of work was classified under 'heavy category'.

(3) *Work rest cycle:*

As mentioned in Table 6, the mean EER was 26.69 kJ/min (6.38 kcal/min). So, the work rest pause in minutes was calculated from equation to be 30 min. Hence it was recommended to give rest pause of about 30 min after each 30 min of continuous operation with the developed power weeder.

4 Conclusions

The developed knapsack type paddy weeder with serrated-flat blade is able to speed up the weeding work of paddy. It has an effective field capacity of 0.031 ha/h with fuel consumption (petrol) of 0.77 l/h. The ergonomic evaluation in terms of acceptable work load, energy expenditure rate, overall discomfort rating and body part discomfort score indicated that the power operated knapsack type roto paddy weeder is heavy for operation. The operator should take rest of 30 min after continues work of 30 min with the developed paddy weeder.

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Chapter 37
Physical Risk Factors Among Workers of Agro-Enterprises by Workplace Ergonomic Risk Assessment

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1 Introduction

Safety and productivity are impacted by the extent to which work stresses the capabilities or limits of the body's biomechanical, physiological or psychological systems.

The term work related musculoskeletal disorder is used in reference to conditions that are called cumulative trauma disorder, repetitive strain injuries or overuse syndromes. All these terms refer to condition that involve muscles, tendons and nerves and usually manifested as pain, discomfort and tingling in a body area.

Most of these disorders have been associated with occupational factors (e.g. force, repetition, awkward or static posture, vibration) and non-occupational factors such as hobbies, underlying disease and personal factors. While studying the MSDs, it is important that all these aspects should be addressed (Vinay et al. 2012). Prevention of WRMSDs is less high-priced than rehabilitation preventative measures which aim to locate the doubtlessly dangerous ergonomic work situation at an early level before WRMSDs occurs (Lohani and Vinay 2015). It becomes most crucial to select the correct and cost-effective method (Bhupender and Deepa 2016).

These agro processing industries in India cover a highly diversified range of sectors. Although in some activities, risks and hazards are common for the whole sector, other risks and hazards are more specific to certain branches of the agro processing industry. One of the general factors shared by all sectors of the agro industry is that they are required to follow strict health and hygiene standards since their products can affect the health of consumers (Sbizue 1993). While performing various tasks at the workplace WRMSDs may occur due to continuous performing repetitive nature of tasks, attaining of awkward postures while working, and strenuous nature of physical work with forceful exertion. Within these agro industries, the key

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risk factors include manual material handling, repetitive motion, slips, trips and falls, machinery-related risk and other hazards.

Therefore, in the present investigation, the WERA method developed by Rahman et al. (2011) was used to identify risk factors associated with MSDs (Rahman et al. 2011). The assessment through the WERA method includes complete human postures, repetition task, vibration, force/strength exertion, contact stress and task duration. The WERA method perfectly fits with the type of activities performed in the agro processing enterprises that were carried out in sitting or squatting postures and in repetitive motion.

2 Methodology

The present investigation was descriptive in nature, describing the emerging problems related with health and safety due to inappropriate work postures or repetitive movement among the workers engaged in the various agro-enterprise activities. The existing literature facts served as a reference for solving problems based on scientific methodological principles to illustrate the relationship between working conditions and workers' health, particularly musculoskeletal discomfort. The data were collected through interviews and observation methods along with video recording.

The following steps were used to identify musculoskeletal discomfort risks or hazards faced by the workers at workplace in different agro-enterprises:

(a) Each task was identified on the existing postures in the job based on the work procedures. This activity was done accordingly to the work procedures.
(b) The angle of the postures formed during performing each task was measured by the video recording. The measurement of angle of the body postures was assessed which starts from the main axis of the spine.
(c) For conducting WERA based on the postures adopted during the task, physical risk factors were assessed which cover different body parts, i.e. shoulders, wrists, neck, back, legs; repetition, force/strength exertion, vibration, contact stress and task duration. These factors for assessment of risk factor are explained as follows:

The risk level was determined according to the obtained WERA score. If the final WERA score falls under the low risk level category that means the task is acceptable and if the total score comes under medium or high risk level then that means the task required some modifications.

The WERA was conducted on seven agro-enterprises, namely, Food Processing Enterprise, Weaving Enterprise, Bead-Making Enterprise, Jaggary Processing Enterprise, Sericulture, Papad-Making Enterprise and a Bamboo Enterprise. The activities, in which women have more than 80% participation, were chosen for the WERA.

In the food processing, the six tasks, i.e. washing of lemon, cutting of lemon, mixing ingredients, packaging, drying and storage were performed by the workers for preparation of lemon pickle. The task of cutting of lemons was identified as difficult by the workers during the observation. Therefore, the lemon cutting activity in food processing enterprises was selected for WERA Assessment.

The data regarding postural analysis was obtained by recording videos and capturing pictures of the workers during performing the task and working procedures required to adjust the positions of the images taken and the tasks done.

3 Results and Discussion

The seven agro-enterprises were selected for the present study. The lemon cutting activity in the food processing enterprise is an example of a calculation of the WERA score. WERA for lemon cutting activity in food processing involved 3 steps. Similarly various activities performed by the workers in the weaving enterprise, bead-making enterprise, sericulture, papad-making enterprise, jaggary processing enterprise and bamboo enterprise were evaluated to assess the final WERA score. By observing the type of posture attained by the workers while performing different tasks, the assessment of posture was done to determine whether the working posture adopted by the workers was hazardous or not. The results of WERA of each investigated task were then compared to another and within all the centers (Table 1).

Table 1 Assessment of shoulder posture

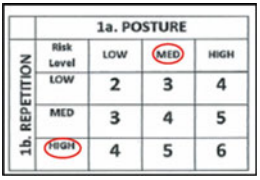
S. No	Posture	Repetition	Scoring system	Score
1		Heavy movement with no rest		5

Fig. 1 Task performance by the workers at food processing enterprise

The WERA for the tasks was examined by measuring the angles of posture adopted by the workers. The angle measurement was based on the human bone structure starting from the spine as the main axis.

Kinovea software was used to calculate the angle of posture for the assessment of the WERA score. The first assessment was carried out on the shoulder posture (Table 1), where an angle of 134° was formed or, in other words, the shoulder is moderately bent up near the chest level. Thus, it was found that the posture of the shoulder had a medium-level score. In addition to this, on the evaluation of repetition, the task of lemon cutting was given a heavy score because of repeated movement of the shoulders with no rest. The frequency of shoulder movements greater than 2.5 per minute were linked with the development of the WMSDs (Bernard 1997). In the present study, the posture assessment of the shoulder was recorded with a score of 5 representing medium risk level for posture with heavy repetition.

Table 2 depicts the second assessment of the wrist posture. Where the wrist of worker was bent moderately due to up and down movements and the worker formed upwards and downwards angles of 129°. Therefore, it was revealed that the wrist posture recorded a medium risk level. Whereas, the repetition assessed in this task was more than 20 times per minute as the hands were continuously kept in a moving position while performing the task. In the scoring system, an obtained score of 5 represents high risk level for the wrist. The external factors such as arm posture, hand loading and dynamic exertion on shoulder muscle activity have an influence on the shoulder joint. The adding of 0.5 kg load to the hand, shoulder muscle activity was increased by 4% Maximum Voluntary Excitation (MVE) (Antony and Keir 2010). A study on wrist movements among females found that the frequency of musculoskeletal disorders was high especially for the right wrist or hand although the work was non forceful and there were minor extreme positions of the wrist (Arvidsson et al. 2003).

The back posture was evaluated as a third assessment during the task performance (Table 3). It was observed that the worker's back was bent, twisted in a forward angle of 18° and a moderate score of 3 which indicates moderate risk level. Whereas the assessment of repetitions, the task was given a high score (5) because the back was moving 9–12 times per minute leading to a high risk level. The back posture was evaluated as having a medium risk level and a high repetition and a high score of 5 in scoring system. The lower back muscle activity was very low during seated posture

Table 2 Assessment of the wrist posture

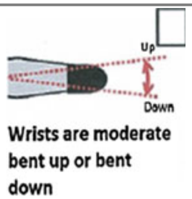
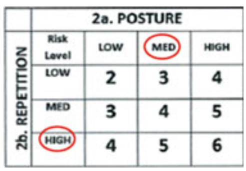
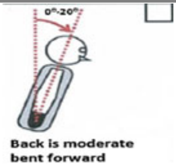
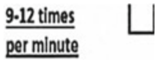
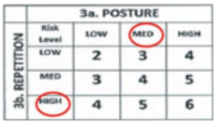
No	Posture	Repetition	Scoring system	Score
2		Over 20 times per minute ☐		5

Table 3 Assessment of back posture

No	Posture	Repetition	Scoring system	Score
3				5

and moderately influenced by work (Mork and Westgaard 2009). The increased risk of lower back pain was associated with increased back movement when carrying out manual handling tasks (Bernard 1997). Back movement, even without pain or depression which was associated with greater repetition, may result in induced submission of pain (Sullivan et al. 2009)

Table 4 shows the estimation of the neck, where the worker's neck formed the angle of 38.72° by bending the neck moderately forward and recorded a medium risk level. Furthermore, the evaluation of repetition of neck movements during the task was recorded as medium risk level because the movement of the neck had some pauses. Therefore, in the scoring, it attained a score of 4 from the estimation of both medium neck posture and repetition. Neck posture is an important risk factor for development of pain in neck region (Straker et al. 2009). Awkward working posture of the trunk, neck and shoulder simultaneously with other factors such as work station layout, design of equipment and tools, and work methods may develop serious MSDs (Keyserling et al. 1993).

The fifth evaluation was done for the assessment of the risk associated with leg posture adopted by the workers during the work (Table 5). The worker performed the cutting task in a sitting posture where the feet did not touch the floor and the leg posture recorded a high risk level. The duration of the task performed was 8 hours per day so a score of 6 was obtained from the evaluation of both leg posture as well as task duration in the scoring system.

The sixth evaluation was performed for the force exertion/the load lifted as depicted in Table 6. There was no load lifted by the worker while performing the task, which revealed that the load lifted was below 5 kg and resulted in a low risk level. Moreover, the earlier estimation of the back posture achieved a medium risk

Table 4 Assessment of neck posture

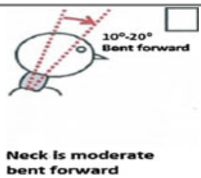
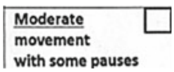
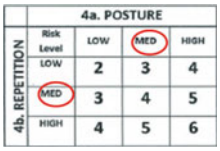
No	Posture	Repetition	Scoring system	Score
4				4

Table 5 Assessment of leg posture

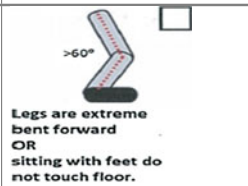
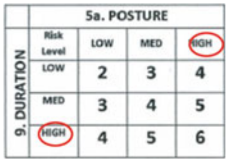
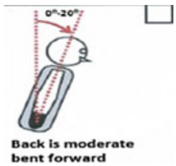
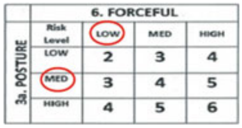
No	Posture	Duration	Scoring system	Score
5				6

Table 6 Force exertion/load lifted by the respondents

No	Lifting the load	Back posture	Scoring system	Score
6				3

level. Therefore, the scoring system for force exertion showed a low risk level for lifted load and a medium risk level for the posture of the back thus recorded a score of 3. The manual lifting was an important risk factor for the occurrence of low back pain (Faber et al. 2009).

The seventh evaluation was done on the use of vibration tools. It was observed that no vibration was made by the tool used while performing this task and obtained a low risk level whereas the assessment of the wrist posture showed a medium risk level as discussed earlier and is depicted in Table 7. As a result, the score recorded was 3 for the vibration tool and a medium risk level was found for wrist posture (Table 8). Several occupational illnesses may result due to vibration transmission from power hand tools to the hand arm system. The risk of hand and arm injury associated with the exposure of vibration transmission direction, arm posture or hand grip force (Besa et al. 2007). The study indicates that the vibrating tools may cause direct damage to muscle fibres as well as nerves (Necking et al. 2004).

Table 7 Use of vibration tool at enterprise activity

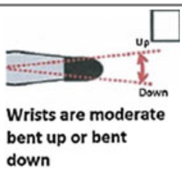
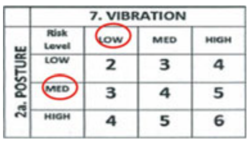
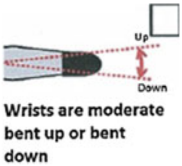
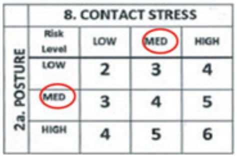
No	Using of vibration tool	Wrist posture	Scoring system	Score
7				3

Table 8 Assessment of tool grip/use of hand gloves

No	Using of tool handle	Wrist posture	Scoring system	Score
8				4

The use of tool grip or gloves was assessed in the eighth assessment (Table 8). It was observed that the worker was using a knife with around wooden handle while performing the task, i.e. lemon cutting and was recorded a medium risk level. In addition, the wrist posture assessment was recorded a medium risk level. Thus, the score of 4 was given for the use of the tool handle and wrist posture assessment. The tool grip is an important determinant of health risk associated with the operation of hand tools (McDowell et al. 2006).

The duration of task performed was assessed as the ninth evaluation. The duration of work performed was for 8 hours and thus obtained high risk level, whereas lifting the load of cutting the lemon was not more than 5 kg and thus associated with low risk level. As the load in cutting was not up to 5 kg, therefore, the activity was categorized in the scoring of the assessment for the high work duration and low lifted load obtained a total score of 4 (Table 9). Task duration is an important risk factor for development of WMSDs of the back, shoulder, arm, hand, wrist and neck (Bernard 1997). More than two consecutive hours of work is critical in combination with other risk factors (Occupational Safety and Health Administration 2000). When daily working time exceeds 4 hours, the rates of WMSDs increase in the back, shoulder and neck especially in a sitting task (Winkel and Westgaard 1992).

The job assessment results of WERA are presented in Table 10. The total final score of 39 for the lemon cutting task of one worker in the food processing unit

Table 9 Assessment of task duration

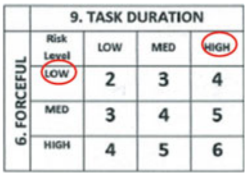
No	Task duration/day	Forceful	Scoring system	Score
9				4

Table 10 Action level of WERA score in lemon cutting task in food processing unit

Risk Level	Score	Action	Score obtained
Low	18–27	Task is acceptable	
Medium	28–44	Task is need to further investigation and required change	**39**
High	45–54	Task is not accepted, immediately change	

was obtained which represents a medium risk level. Hence, this task needed further investigation and change is required (Table 10).

Similarly, the assessment of the WERA score was done for all the selected agro-enterprises and was given as follows. Table 11 depicts the average WERA score of physical factors, performed by workers of selected enterprises among all the centers of AICRP (Home Science), FRM component.

In the food processing unit, 88 respondents engaged in various activities like the lemon cutting activity (28 respondents), squash preparation activity (30 respondents), and vegetable cutting and chopping activity (30 respondents). Based on the average WERA score calculated for the food processing unit workers, the highest risk score was obtained for the wrist (5.49) and shoulder (5.25), where the shoulders of workers were in high bent up posture and high twisting of wrist with moderate repetition. Greater than 60º of repeated or sustained flexion of the arm while working may develop shoulder disorders (Bernard 1997). Back (4.89), neck (4.61), leg (4.30) and contact stress (4.33) obtained a medium risk level. No personal protective equipment was used by the workers while performing the task and they performed activities with high repetitive movements by adopting awkward posture. The unavailability of personal protective equipment may lead to cuts, abrasions, tingling and vibrations which over time put negative impact on the worker's health. The results of Table 11 showed that applied force, vibration and task duration gained a score >4. The respondents were not engaged in lifting of any load nor did they work on any vibrating tool. The task was performed by food processing workers for more than 4 h per day. Therefore, the average WERA score of 39.5 was obtained for the workers engaged in the food processing enterprise, depicting that risk factors involved in different activities were having a medium risk level and the task needed to be further investigated and required changes.

The WERA on the bead-making enterprise was conducted on 30 workers. Table 11 revealed that the risk factors associated with leg posture were high in bead making as work was carried out for 8 h per day in sitting position thus obtained a score of 6. However, risk factors related with the shoulder, wrist, neck, tool vibration and contact stress obtained a score of 5 each. Shoulders and neck were moderately bent up and repetition was high while in the case of the back it was medium. Meanwhile workers tried to change the posture and worked in a squatting posture for 10–15 min. The bead work was carried out on a high vibrating machine continuously for 8 h with some rest pauses with wrist posture having a score of 5 and also the work was carried out without using gloves. Therefore, the average WERA score of 42 was obtained for the workers involved in the bead-making enterprise, and depicting risk factors

Table 11 WERA score of the respondents engaged in 7 agro-enterprises N = 283

Enterprise	Risk factor									
	Posture					Forceful	Vibration	Contact stress	Task duration	Final score
	Shoulder	Wrist	Back	Neck	Leg					
Food processing unit (n = 88)	5.25	5.49	4.89	4.61	4.3	3.45	3.42	4.33	3.75	39.5
Bead enterprise (n = 30)	5	5	4	5	6	3	5	5	4	42
Jaggary processing unit (n = 30)	3.5	4.5	6	4.9	3.6	2	2	6	5.9	38.4
Sericulture (n = 30)	4	4.67	4.67	4.33	5	3.33	2	2	4	34
Papad making (n = 30)	4.5	5.5	4.6	4.75	3.62	2.37	5.25	2.87	5.5	38.96
Weaving enterprise (n = 45)	5.12	5.7	5.84	4.72	5.88	2	2	2	5.92	39.18
Bamboo production enterprise (n = 30)	4	3	3	4	4	2	2	2	2	26
Average (N = 283)	4.48	4.84	4.71	4.62	4.63	2.59	3.10	3.46	4.44	36.86

were at a medium risk level and the task need to be further investigated and required changes to reduce the risk level.

Assessment of workplace ergonomic risks in the Jaggary processing unit was conducted on 30 workers. The highest risk factors observed for Jaggary processing workers were for the back and due to contact stress where the back of the workers was extremely bent and repetition was more than 12 times per minute. During the Jaggary ball making activity, the wrist of the worker obtained a score of a high risk level due to an extremely bent up and down wrist position. This operation was performed without using gloves and gained a score of 6. The work was carried out for more than 8 h per day without lifting the load which gained a score of 5.9. The score of wrist and neck were 4.5 and 4.9, respectively. The shoulder (3.5) and leg (3.6) were under medium risk level. The Jaggary ball making activity was performed in a squatting posture and workers were neither lifting any load nor using any vibration tool. Hence, the average final WERA score of 38.4 was obtained indicating that the task needs to be further investigated and required some changes.

The WERA for Sericulture enterprise was conducted on 30 workers. The extraction of pupa from a cocoon activity was selected for the workplace ergonomic risk assessment of workers. The highest risk factor was found for the leg posture as the work was carried out in a squatting posture for more than 4 h per day. However, the risk factor for the wrist, back and neck obtained a score of 4.67, 4.67 and 4.33, respectively. At the time of extraction from the cocoon, the wrist was moderately bent up and down for 11–20 times per minute. Similarly the posture of the back and neck maintained a moderately bent forward with moderate repetition and recorded a medium risk level. Whereas, shoulder and task duration obtained a score of 4 for each, because the shoulders of workers were near to chest level or moderately bent up with some pauses. The task was continued for >4 h per day. Regarding the forceful nature of the task, no weight was lifted by workers resulting in attaining a score of 3.33. The task was performed without using any hand gloves or vibration tools and thus obtained a score of 2 for each. Hence, the average final WERA score of 34 was recorded for extraction of the cocoon in the sericulture activity which depicts that the task needs to be further investigated and required changes as well.

Thirty workers were selected for the WERA score analysis on the papad-making enterprise. In this enterprise, the process of papad making was semiautomatic and the workers were involved in several activities. The risk factor of wrist postures was high as work was performed by the wrist in a moderately bent up and down position with repetition of 11–20 time per minute which gained a score 5.5. The task of making papad was conducted on a high vibrating machine continuously for more than 4 h per day having a score of 5.25. A score for the shoulder, back and neck was 4.5, 4.6 and 4.75, respectively. The posture of the leg had a medium risk level as work was carried out for >4 h in a sitting with feet position flat on floor, and attained the score of 3.62. However, change in posture was observed for 10–15 min after an hour's work. As far as work was concerned with less than 5 kg weight lifted by the workers and thus recorded a score of 2.37. Moreover a score of 2.87 was obtained as the work was performed without using any gloves. The overall average final WERA score was obtained as 38.96, which indicates that the risk factors were associated with medium risk level and defined that the task needed to be further investigated.

The WERA of the weaving enterprise was conducted on 45 workers. The activity of weaving was performed on a loom in a sitting posture on wooden stool. It was revealed from the assessment that the highest score (5.92) was obtained by task duration because the work was carried out for more than 8 h's duration. The leg (5.88), back (5.84), wrist (5.7) and shoulder (5.12) obtained a medium risk level score. The work was conducted with rest pauses and the movement of wrists and back were more than 20 time per minutes. A score of 2 was obtained because no load was lifted by the worker at the time of weaving. A similar score for vibration made by tools and contact stress was obtained as no hand gloves and vibrating tool was used at the time of task performance at the work place. Therefore the final average WERA score in the weaving task was recorded as 39.18, which depicted that workers were at medium risk level and the task needed to be further investigated and required changes.

The WERA for the bamboo enterprise revealed that the shoulder of the workers while working on the bamboo enterprise were moderately bent up and movement was with some pauses resulting in obtaining a score of 4. Neck and leg postures were at medium risk as these body parts were moderately bent forward. The repetition of the neck was associated with medium risk and the posture of the leg showed medium risk as the duration of the task was for 2–4 h per day. Hence, the neck and leg obtained a score of 4 for each. However, a score of 3 was obtained for the wrist and back, as the back and wrist were moderately bent up and the repetition was also low. Regarding the forceful nature of the task, vibration, contact stress and task duration, the score was 2 for each attribute. Workers were not lifting any load and not using any vibrating tool while performing activities in the bamboo enterprise. The task was performed without wearing hand gloves for 2–4 h per day. Therefore, the final WERA score of 26 was obtained, indicating that workers were at low risk which means the task is acceptable.

The result of Table 11 envisaged the physical risks based on the obtained WERA score for each risk factor for workers of selected agro-enterprise. The result of the WERA score analysis revealed that the final score of all selected agro-enterprises activities depicted medium risk level which indicates that all the tasks need to be redesigned for reducing the discomfort level of workers performing different activities of the selected enterprise. The applied ergonomic principles while designing the workplace and working tools and equipment may reduce the chances of musculoskeletal disorders and prevent injury among the workers.

4 Conclusion

Work-related musculoskeletal discords in seven agro-enterprises vary based on the exposure to the risk factors like prolonged working hours, awkward postures while working, repetitive nature of work and in appropriate working of tools and equipment.

The physical risks based on the WERA score for each risk factor for workers of these seven agro-enterprises revealed that there is a medium level of risk in all these selected agro-enterprises activities with the score of 28 to 44 where as in bead-making enterprise the WERA Score was 42 which indicates that all the tasks need to be redesigned for reducing the discomfort level of workers performing different activities of the selected enterprise. The hazards and related MSDs of the workers may reduce to a considerable extend through given intervention so that the task can lie under acceptable task category. Workplace ergonomic risk assessment assures that work environment (workstation, tools and equipment, posture and work procedure) is properly designed in order to maintain worker's safety and health thus increased productivity, efficiency and work quality.

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Chapter 38
Product Design Intervention to Solve Issues Faced by Construction Workers in Glass Cleaning Activity

Reenu Singh, Rauf Iqbal, and Ashok K. Pundir

1 Introduction

The workforce engaged in construction activity in India consists of engineers, managers, technical/foremen, clerical, skilled force and unskilled workers. Indian construction labor formed around 7.8% of the total construction labor in 2014 (Kulkarni 2007). With increase in construction activity each year there has been a steady increase in demand of the construction labor as of now. Barring the negative effects of Covid 19 pandemic over the labor-intensive industries like construction industry.

2 Issues Faced by Construction Workers

Construction project includes several steps including construction of the structure setting up provisions of electrical connections, plumbing layouts and finally finishing work. Finishing work of building construction includes plastering, installation of glass paned, balcony railing, fittings and fixtures, painting and final cleaning of all surfaces. Studies related to improvement of tools of construction workers are elusive in the literature. The workers use make do arrangement to carry out their tasks. Construction workers use Jugaad objects (Singh et al. 2017a) such as mild steel plate for putty application, rags, discarded paint buckets, etc.; in absence of proper tool and equipment, the repetitive prolonged physical task is tiresome and unsafe for

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finishing workers (Singh et al. 2016) which is similar to physical strain experienced by other manual construction workers (Singh et al. 2019). Few studies have been carried out on the occupational musculoskeletal disorders (MSDs) of construction workers (Wang et al. 2017) but studies related to glass cleaning workers still needs attention.

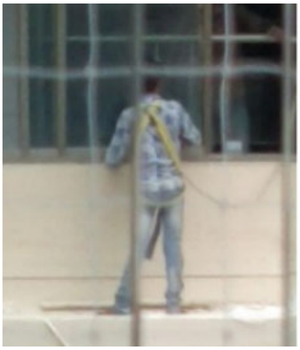
3 Glass Cleaning Workers

Contemporary high-rise residential buildings (National Building Code (NBC) 2005) in metros have glass windows which occupy a large amount of the elevation. Newer modern residential buildings have floor-height sliding panels (Moon et al. 2015) which are akin to French windows. Conventional task of glass maintenance involves unskilled labor workers who are young migrants. Glass cleaners do the job in narrow spaces and thus is hazardous. In times of windy weather and rain these workers are at risk of losing slipping off the narrow projections (Tiwary and Gangopadhyay 2011; Haslam et al. 2005). The workers suffer from severe injuries due to falls and collisions on the wall due to slips while performing their task with the make do tools along and maintaining balance at the same time in open balconies of high-rise buildings.

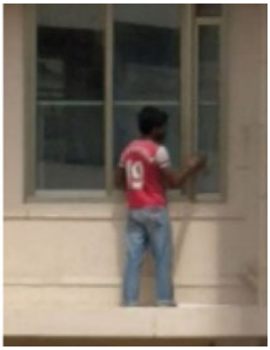
4 Task Study of Glass Cleaning Workers

Glass cleaning workers work similar to exterior wall painters. The differentiating factor lies in the objects that are carried by them. Glass cleaning workers were studied to understand the task process. The following table provides the details of the postures of tese workers. Figure 1 depicts screenshots of painting and finishing

Fig. 1 Screenshots of glass cleaning activity of construction worker in Mumbai, India



Glass cleaning worker cleaning the window, standing on the 2' deep projection.



Worker cleaning the window glass and frame.

tasks performed by finishing workers employed at a newly constructed residential building in Mumbai, India.

The finishing workers of glass perform various types of movements. Following (Table 1) is a list of of the sequence of movements and tasks while cleaning the window pane (size is $5' * 3'$ (3 glass panes in total)).

The task of cleaning the glass includes prolonged hand and shoulder movement. Currently the glass cleaning workers use a rag for rubbing the stains and dust off of the surface. Issues with the functionality of the existing glass cleaning cloth were.

1. Cleaning cloth falls down (loose grip)
2. Removing stains along edges and sharp corners is difficult
3. Effective on a small area with the hand contact
4. The hold is less effective (grip combined with press force)
5. Low motivation.

However, sensitivity of stains through the fabric of the rag and light weightness were found advantageous in cleaning the window glass. There is a need to design a product that would ease the work and reduce the physical strain. User-centered design approach was used which was useful to design hand-held blender. Therefore, design parameters were drawn with the help of the insights from the task study in Table 2. The glass cleaning workers would potentially benefit with the new tool that will fulfil the following expectation.

1. Hand held
2. Sensitive to the surface-unevenness
3. Remove stains along edges and sharp corners
4. Pliable for application of pointed force
5. Drop safe
6. Easy to hold.

5 Design Ideation

The above-mentioned expectations of the glass cleaning tool were used to formulate ideation. The ideas fulfil some of the expectations; however, each idea scores better than the other for functional expectations. The three ideas are illustrated as follows.

Idea 1

The handheld tool is comprised of a glove (Fig. 2) which has an added moderately hard plastic and a thick sponge at the base. The sponge is semi-hard which retains its corners and edges after absorbing cleaning liquid and water.

Idea 2

The tool consists of a triangular plastic pad with a semi-rigid sponge attached at its base. The top of the plastic plate has a handle (Fig. 3). The sponge retains its edges and semi-rigid texture after absorbing cleaning liquid or water.

Table 1 Task study of glass cleaning by construction worker in newly constructed residential building.

S. No	Movement/Task	Duration
1	Procurement of cleaning material (rag, water container, dry mop, rough newspaper) and bring it close to the window—done by a companion or by self	2 min
2	Accessing the window to reach the outside parapet or balcony platform (depends on the floor height and balcony/parapet level outside)	30 s
3	Tie up the safety harness (Needs assistance from fellow worker in pulling ropes from back to front)	1–2 min
4	Remove the remains of dust and other remenants of the construction finishing material including small sticks, small pebbles, paper, discarded material bag, polythene garbage and others	5 min (for 20 square feet area of the balcony or parapet)(Optional activity)
5	Collecting and putting the dirt and garbage in fist and placing it in the inside of the apartment on the floor close to the base of the window inside the room	30–60 s (Optional activity)
6	Wiping the glass with wet rag- involves repetitive movements which are either linear or circular	6 min with breaks
7	Wiping the glass with dry mop or Rubbing the surface with newspaper (for the lower portion of the glass area which is within worker's reach (lower 50% of the glass panel length) while standing on the balcony)	6 min with breaks (optional)
8	Wiping of the external surface of the window frame using the wet rag (for the lower portion of the glass area which is within worker's reach while standing on the balcony)	6 min with breaks
9	Picking up the cleaning paraphernalia (wet rag, container filled with water, dry mop, rough newspaper) and passing to the fellow cleaner who is inside the room	2 min with breaks
10	Untying the safety harness	1 min
11	Picking the wet rag and dry mop or newspaper handed by the fellow worker. Stuffing the dry mop in fist of another hand or his trousers pocket	1 min

(continued)

Table 1 (continued)

S. No	Movement/Task	Duration
12	Wiping the glass with dry mop or Rubbing the surface with newspaper (for the upper portion of the glass area which is within worker's reach while standing astride on the window railing)	6 min with breaks (optional)
13	Wiping of the external surface of the window frame using the wet rag (for the upper portion of the glass area which is within worker's reach while standing on the balcony). The body is supported on the railing of the balcony rod but torso is uncomfortably protruded out as the worker is not facing the glass now he is on the same plane as the glass	6 min with breaks
14	Worker hands the water container and gets off the balcony railing. Followed by removal of the safety harness	2 min
15	Glass cleaning task is complete	Total time 39–46 min

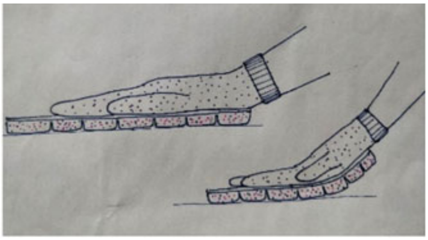
Table 2 Fulfiled expectations of design parameters by the ideas.

Idea no	Expectations fulfilled by ideas
1	1. Handheld 2. Sensitive to the surface unevenness 3. Remove stains along edges and sharp corners 4. Pliable for application of pointed force 5. Light weight 6. Drop safe 7. Easy to hold
2	1. Handheld 2. Remove stains along edges and sharp corners 3. Light weight 4. Easy to hold
3	1. Handheld 2. Remove stains along edges and sharp corners 3. Light weight 4. Easy to hold 5. Cleans wider surface in each stroke

Idea 3

The tool consists of a central disc which has a pair of plastic bands fixed at the base. The plastic bands have a semi-rigid foam attached at the base to absorb cleaning liquid and water. The plastic bands are mobile with mechanical action that facilitates circular movement. The up–down movement of the worker allows the plastic bands to move around in circular motion like a flap (Fig. 4).

Top view of the glass cleaning tool

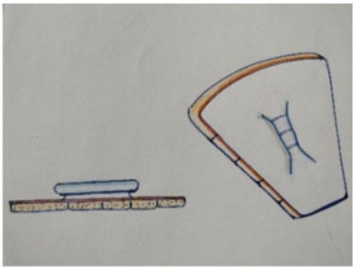


Side view of the cleaning tool

Fig. 2 Idea depicting a wearable tool

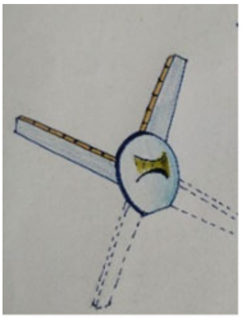
Fig. 3 Idea depicting a hand-held plastic board with a rigid foam at the base

Top view of the tool with the handle at the centre.

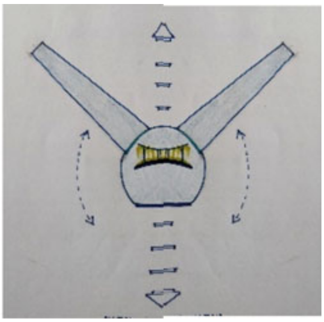


The side view depicts the handle on the plastic plate and the bands of the semi rigid foam.

Fig. 4 Idea of tool with movable pair of cleaning bands



Side view



Front view

The comparisons of the four ideas listed below in Table 2 show the fulfilled expectations by each idea.

Among the four ideas, Idea 1 fulfils the greatest number of expectations. To understand the product detail and functional viability, mock-ups and prototype of idea 1 will be made in varying configuration and modifications. Insights from the

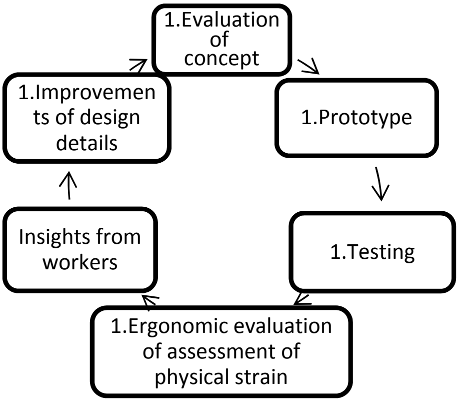


Fig. 5 Steps of user-centered design

mock-ups will be helpful in designing a final concept that will be useful in making a prototype of the final concept.

6 Future Steps of Design

Following User-Centred Design method (Kling 1977; Norman 1996) of design and testing of the improved glass cleaning tool, the following figure denotes the sequence of process of concept evaluation followed by prototype testing, ergonomic assessment and design improvements (Fig. 5).

7 Conclusion

This symptoms of musculoskeletal disorders (MSDs) can be reduced with design intervention. Painting tools that are designed for better provision of grip and farther reach will alleviate physical strai of the glass cleaners. Tool design with focus on the user ease and improved body interaction of the worker with the tool operation will improve the overall task of the glass cleaning (Singh et al. 2017b). The climbing up and down is risky in cases when workers do not wear their safety harness. Additionally, task study will provide insights about areas of improvement of job design and other assistive paraphernalia entities. Issues faced in the wearability of the safety harness is missing and thus should benefit in proposing problem-solving measures for improved wearability. The whole system of the task of glass cleaning can be made easier and stressfree by proper design interventions for actions which otherwise lead to severe strain in upper body parts. With better methods of collaboration between countries, improved job design and usage of specialized tools could open service avenues for the workers to other developing countries (Singh et al. 2017c). Therefore, improved tools and equipment design will increase efficiency of the workers. Furthermore focus on improvement of their tool/equipment will increase productivity of the building completion and successive finishing activity.

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Chapter 39
Psychological Survey of Color Perceptions for Indian Users

Siddhant Patil, Ganesh Bhutkar, and Prakash Vaidya

1 Introduction

Color is a powerful communication element, which can be used to signal action, influence mood and even influence physiological reactions (Cherry 2020a). It has been seen that some colors are related to increased blood pressure, metabolism and eyestrain. Color affects human feelings along with one's memories. A color therapy technique, also known as chromotherapy, is a prominent alternative medicine method. It involves a use of selected colors to treat different kinds of diseases (Bailey 2019). One area where the color psychology is put into effect is in the fields of marketing as well as design. Color plays a major influence on the customer's selection of a product. Brands and companies utilize colors for their brand logos as a trick to allure the customers. This happens when the colors associated to the logos tend to resonate with the personality of the customers; they get attracted to the company's products.

Color psychology can be defined as a study of how colors affect behaviors and perceptions of users or customers (Ciotti 2019) and the theme of this survey was to understand the Indian users' perception about colors and to identify their favorite colors. As a result, this survey was named as 'Psychological Survey of Color Perceptions'. Humans' perceptions of colors differ from person to person. How a person

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perceives and responses to a certain color is very subjective. Multiple factors play a role in determining color perception and these factors include age, gender and culture (Bailey 2019). Another important factor would be an intimate relation or connection with a specific color. For example, let us consider a person who as a child had a favorite cartoon character who was red in color, then it is very likely that whenever he is in a situation where he has to choose a product or service based on his favored color, his inclination will be toward the red color (Chapman 2019).

Although, due to universal human experiences, there is a chance of guessing how customers might react to certain common colors, but not all of them. Customers relate the color green to nature, as a result of being witness to the growth of plants and trees. For the color blue, it has been related to the emotion of calmness and trust, as this gets evoked when people view elements of nature like sky and water (Chapman 2019). But there are many other colors that need to be understood along with emotions they invoke. There have been a few global studies conducted to understand the color psychology of the users, but there isn't any study conducted specifically for the Indian users. This has been a real motivation behind conducting this user study.

2 Literature Review

We encountered few research papers and blog or magazine articles during literature review related to color psychology, favored colors and other user studies. These research papers and articles are discussed widely in this section.

The first study titled 'Color Assignment', is basically a website showcasing a research project having a goal of discovering the cultural differences based on the color preferences, associations and Internet activities. This user survey has questions inquiring about emotions related with color representations (Hallock 2003). The main aim of this study was to provide color combinations and favored colors to facilitate designers in making better color choices when designing products or applications. This research provided the colors that evoked certain emotions and qualities. Moreover, it also informed about the most and the favored colors by genders, as well as age groups. This study has helped in understanding the process of creation of the user survey and information about the emotions and the colors.

Second article is focused on the topic 'Color, Psychology and Design' published on UX Planet. The article explains about the differences in the preference of colors according to the gender (Batagoda 2017). It has highlighted that selection of a certain color is dependent upon what emotion the designer desires to portray with that product or service design. Further, it has explained what impact the colors—Blue, Black, Red, Pink and Green, have on that design. This article has provided insights on the impact of these colors, which has further helped in selecting of certain colors for the survey.

Another article about 'Colors and Emotions' published at https://99designs.com has explained about how colors and emotions are linked to each other. It has illustrated the effects of warm colors, cool colors, monochrome colors as well as happy colors on the human psychology and emotions evoked after viewing them (Gremillion 2019).

The colors and the emotions selected for this research work were chosen from this article.

Next research paper titled ‘A Note on Adults’ Color-Emotion Associations’ was targeted on understanding the color-emotion associations of 20 men and women using a questionnaire that included questions about preferred color, color of their clothes, their emotional response to colors and reasons for the same (Hemphill 1996). This study assisted in realizing the emotional responses of men and women for different colors.

The last research paper ‘Color Psychology in Marketing’ explained the literature that connected the color psychology to the marketing of products to determine that colors are significant contributors in marketing. It touched many points that had impact on them due to colors. The various points related with colors were health, culture, emotions, gender and branding (Khattak et al. 2018). This study provided a theoretical understanding about how colors impacted marketing of products and has been taken into consideration during this user study.

3 Research Methodology

This section has a discussion on vital process of research methodology, which includes various stages such as selection of colors, design of user survey and response of participant users.

1. **Selection of Colors**:

The colors are categorized as basic colors, warm colors, cool colors, monochrome colors and/or happy colors (Gremillion 2019). In order to identify favorite colors and the user-emotions evoked, 11 colors were selected to be included in the survey form. These 11 colors were Red, Orange, Yellow, Green, Blue, Purple, Pink, Brown, Black, White and Grey. According to the article on 99designs, these 11 colors are the most popular and liked by everyone (Gremillion 2019). As a result, these specific 11 colors were chosen. These selected colors also have enough representation of all color types.

2. **Design of User Survey**:

The survey form created was decided to include a total of three sections. These sections include a section each on personal details, colors and related emotions, and favorite colors. The first section has asked personal details about user such as, email id, gender and age group. The age groups have ranges such as 13–22 years, 23–59 years and 60+ years.

For the second section, the images of the 11 colors are included. For every image, a dropdown menu is provided showcasing a list of 11 emotions. The major objective behind creating this section was to understand what emotions were invoked among the users after viewing the colors displayed. In the last section, we wanted to find out the favorite colors of the Indian users. This was done by providing the images

Table 1 Distribution of valid user responses in the survey, among user groups

Group No.	Age group (in years)	No. of users		Total valid users
		Male	Female	
1	13–22	87	75	162
2	23–59	47	14	061
3	60+	02	00	002

of each of the 11 colors. All the images were titled with the names of the respective colors. The user was asked to choose his/her maximum of three favorite colors.

3. **Participant Users**:

The user survey has been created for Indian users, representing huge Indian population. The targeted users are divided into three major groups as per their ages. These groups are

User Group 1 (13–22 years): This specific age group was targeted toward the teenagers and bachelors. The age group limits of 13 and 22 are selected as the minimum age for teenagers is 13 years and average age of marriage for Indians is about 23 years (Times of India 2017). The users in this age group have a specific understanding of colors and emotions.

User Group 2 (23–59 years): This specific age group was selected as it depicts huge adult population. Also, the average minimum age for marriage in India is 23 and the retirement age is 60 (Trading Economics 2020). This is the reason for selection of these age limits for this group.

User Group 3 (60+ years): This age group represented senior citizens over the age of 60 years.

Our target was to receive responses from over 200 Indian users, including about 70 female users. This survey was prepared with Google Forms and forwarded to targeted users through shareable link of the user survey through a popular mobile messenger app—WhatsApp. The survey was forwarded to about 300 Indian users. Only 226 users responded actively to the survey form. The response of one user was discarded and not considered for further analysis due to lack of seriousness in his survey response. A distribution of valid user responses to the user survey is depicted in Table 1.

4 User Survey

A user survey was created using Google forms in order to collect data from the Indian Users. This survey consisted of three sections as discussed ahead:

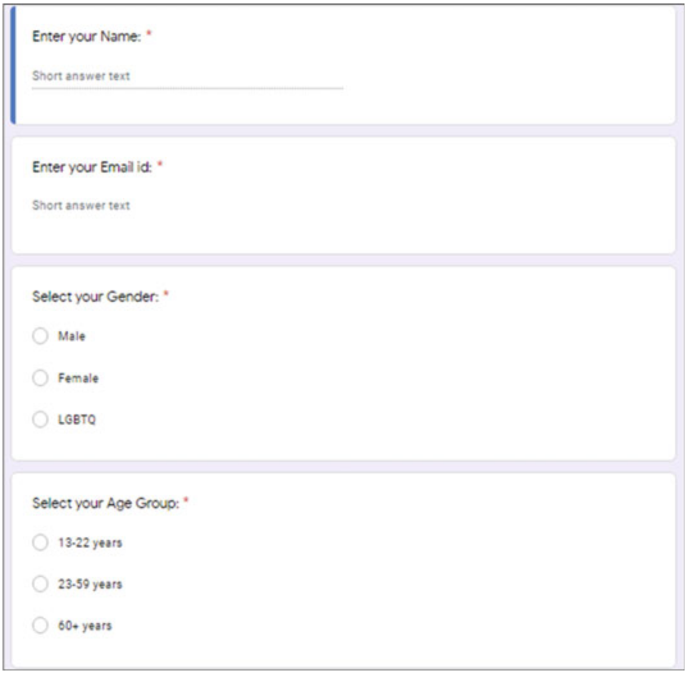


Fig. 1 Screenshot of personal information in user survey

First Section:

The user survey started with instructions about entry of mandatory personal information. This personal information included username, his / her mail address, the gender and age group as seen in Fig. 1. The gender entry was made more inclusive with Lesbian, Gay, Bisexual, Transgender and Queer (LGBTQ) option. The three options for age groups were 13–22 years, 23–59 years and 60+ years of age as discussed in Sect. 3.

Second Section:

This section of the user survey presented 11 colors, which are selected as discussed in section III. These colors included Red, Orange, Yellow, Green, Blue, Purple, Pink, Brown, Black, White and Grey. These colors were presented in a rectangle along with name of the color as seen in Fig. 2. Just below the color rectangle, a dropdown menu was provided. This menu listed 11 emotions which included Fear, Calmness, Happiness, Excitement, Romance, Trust, Purity, Mystery, Maturity, Anger and Stability. The colors and related dropdown menu for emotions were provided as shown in the Fig. 3. The user was asked to select the emotion that is evoked looking at the color presented.

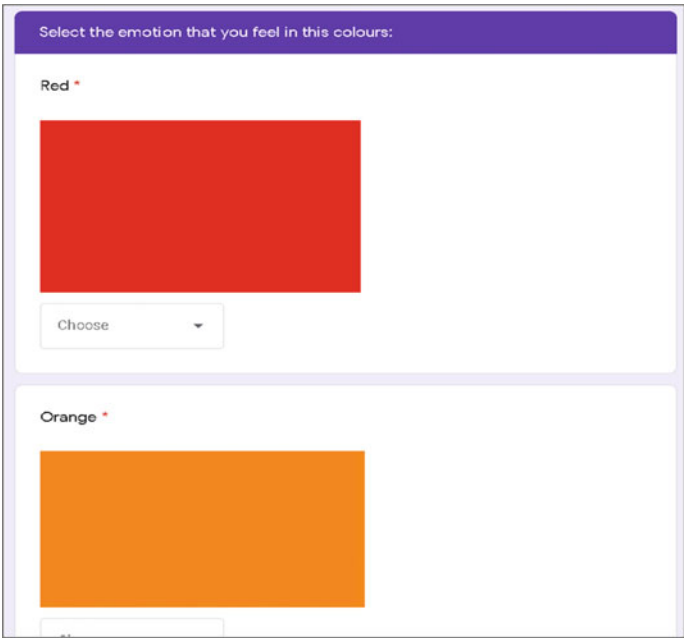


Fig. 2 Screenshot showcasing the colors and related dropdown menu

Third Section:

Third and the final section of the survey again presented same 11 colors to the users as depicted in Fig. 4. Each user was asked to choose a maximum of three favorite colors among these 11 colors.

5 Results and Discussion

A total of 225 valid user responses have been received. Out of these responses, 39.1% users were females. For the age groups, 72% of the responses received are from the age group of 13–22 years, 27.1% from the age group of 23–59 years and 0.9% from the 60+ age group.

The results of the second section about emotions evoked for colors are presented here. An emotion is noted, only if at least 45 users (20% of total 225 users) have voted for an emotion for a particular color.

According to the user responses depicted in Fig. 5, Red color has been voted to evoke the emotion Anger (about 50%) and next, Romance (about 20%).

The color Orange, according to responses shown in Fig. 6, evokes the emotion of Trust (about 32%).

For the color Blue shown in Fig. 7, the responses show that it evokes the emotion

Fig. 3 Screenshot from the survey showcasing the list of 11 emotions included in the dropdown menu

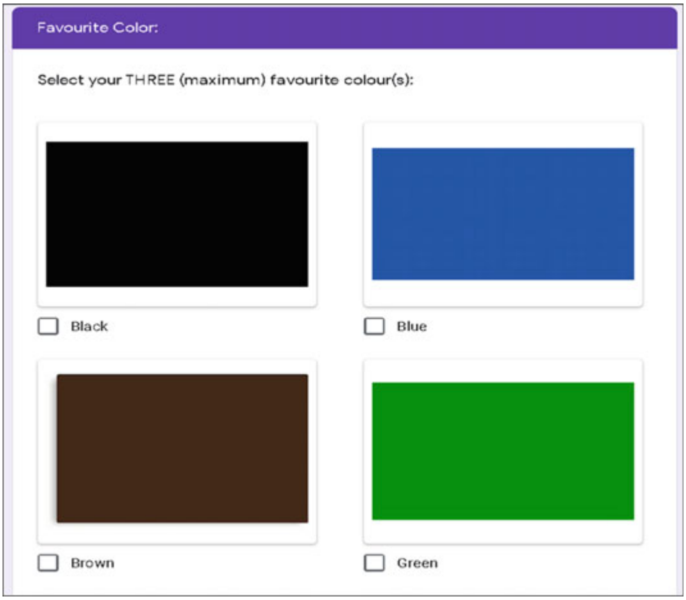


Fig. 4 Screenshot for selection of three favorite colors

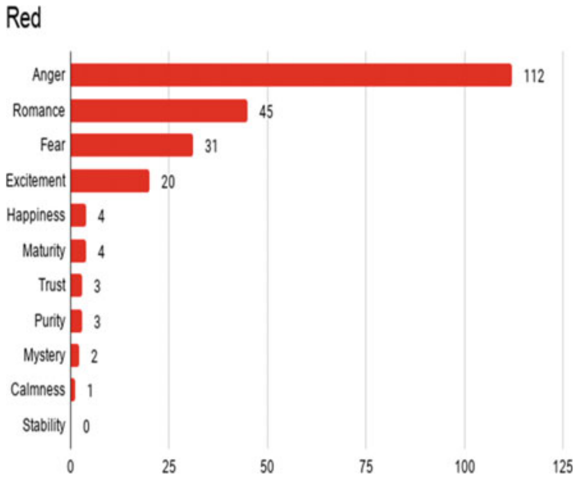


Fig. 5 Bar graph showing the emotions selected by the users the color—Red

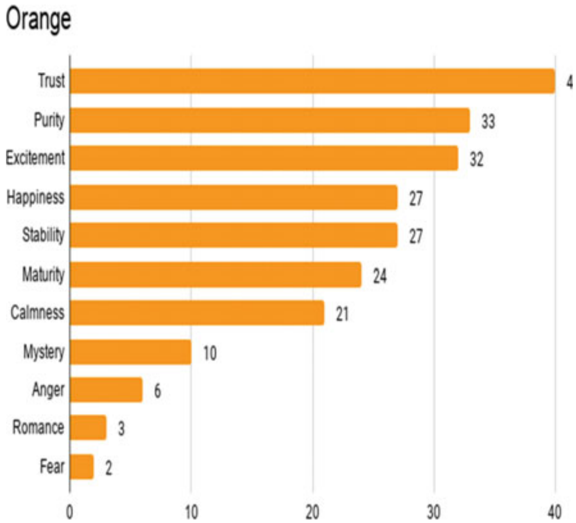


Fig. 6 Bar graph showing the emotions selected by the users the color Orange

of Calmness (about 32%).

For the color—Brown shown in Fig. 8, emotion of maturity has been voted the most with 23%.

Similarly, several emotions are also evoked for remaining seven colors as well. The responses received are compared with these expected emotions in Table 2.

A deviation in the expected emotions in comparison with obtained emotions is observed in the colors—Orange, Blue, Brown and Grey as highlighted bold in Table 2.

A deviation in the emotion associated with a color—Orange, has been seen from excitement to trust. This can be due to the reason that orange color has a significant

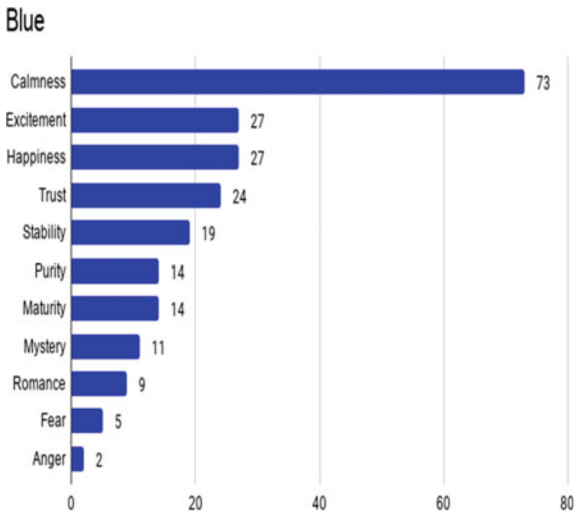


Fig. 7 Bar graph showing the emotions selected by the users the color—Blue

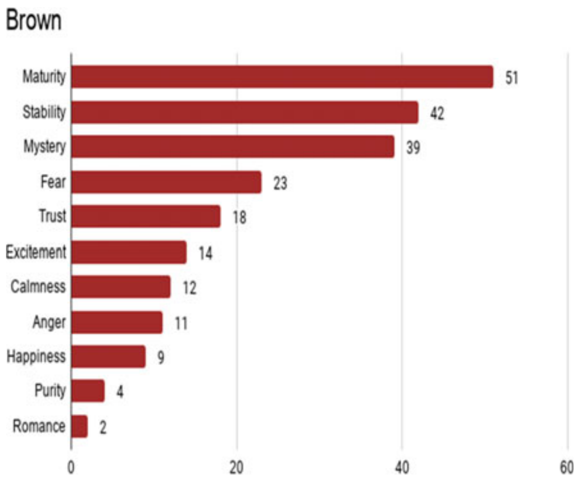


Fig. 8 Bar graph showing the emotions selected by the users the color—Brown

use in depicting various religious aspects of the Indian culture. It is often resonated with Hinduism where in the gods are often shown wearing Orange clothes (Hindu Portal 2015). Due to this use, Indian people tend to feel an emotion of trust when they view the color—Orange.

A deviation in the expected and the obtained emotions for the color-Blue can be interpreted to the fact that the Blue color comes into the category of cool colors. There are many emotions that are evoked after observing the color Blue like trust, calmness, spirituality and security (Gremillion 2019). It was expected that the emotion of trust will be evoked for blue color, but Indian people associated calmness with Blue. This could be due to the fact that the color of the sky and the ocean, which are the main

Table 2 Table showcasing the comparison of the expected emotions and the obtained emotions during user survey

Selected colors	Expected emotions	Obtained emotions
Red	Anger	Anger
Orange	**Excitement**	**Trust**
Yellow	Happiness	Happiness
Green	Calmness	Calmness
Blue	**Trust**	**Calmness**
Purple	Mystery	Mystery
Pink	Romance	Romance
Brown	**Stability**	**Maturity**
Black	Fear	Fear
White	Purity	Purity
Grey	**Maturity**	**Mystery**

elements of the nature, are blue in color. People tend to feel relax and calm when they look at the sky and the ocean (Gregoire 2017). As a result, the emotion of calmness has been associated to color Blue by the Indian users.

Another deviation in people's association has been observed for the color brown. It was expected that people will choose the emotion of stability, whereas the results show that Indian people have associated the emotion of maturity with the color brown. This could be because the brown color is generally preferred by adult and older people; more specifically older men when it comes to their clothing and accessories (Brown 2016). As a result, brown color has been associated with maturity.

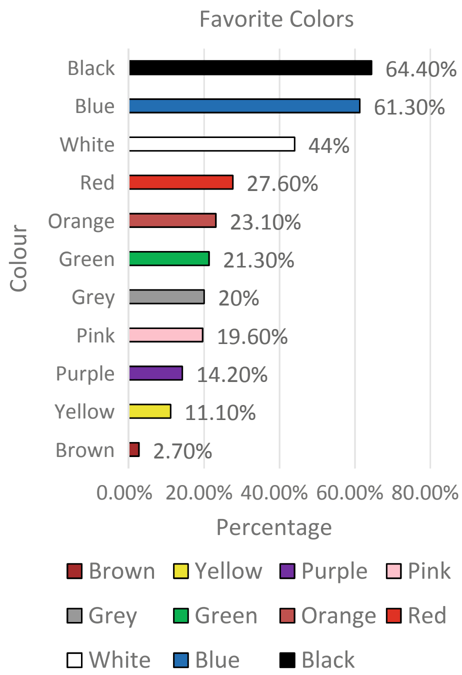
Lastly, a deviation has also been observed in Indian people's association of the color Grey. The emotion with which people had associated grey color was mystery, as opposed to the expected emotion of maturity. This could be a result of the use of color grey often done to showcase a dark, mysterious vibe in movies and television shows, wherein the logos and the titles of the movies are represented with grey.

In this user survey, the third section focuses on choosing favorite colors of Indian people. Related results are presented in the graph shown in Fig. 9.

According to responses received to the user survey, Black, Blue and White have been selected as the most favorite colors. Black color has been selected by 145 users out of 225 users, i.e. 64.44%. Blue has been selected by 138 users, i.e. 61.33%, whereas White has been selected by 99 users—44.00% users.

The color Black emerged to be the most favorite color by the Indian users. This is due to the fact that Black is an elegant color, which reflects luxuriousness and seriousness in terms of formality (Cherry 2020b). As a result, many brands use the Black color in their logos and products. Also, the color Black is very versatile in terms of clothing and it can be combined with any other color. Being a neutral color, Black is used in UI of websites or mobile apps in the form of text color and themes in the recent times which users love to use (Malkani 2015). Thus, Black is the most favorite color of the Indian People.

Fig. 9 Bar graph showing the favorite colors of Indian users obtained during user survey



Followed by Black, the color Blue turned up to be the second-most favored color of the Indian users. This is because it is a universally liked and very easy to pick color due to its calming effect on the eyes (Cherry 2020c). Moreover, when it comes to clothing like t-shirts and jeans, Blue is such a type of color that tends to look good on each and every individual irrespective of the gender. Also, Blue is the most popularly used color in the user interfaces and icon of the IT applications like Facebook, PayPal and Twitter as it is a very comforting color to users and makes them feel at ease when using the apps (Amanda 2016).

The third-most favored color selected by the users came out to be as White. As White color oozes the image of cleanliness and purity (Cherry 2020d), it is favored by a lot of people. Also, being a monochromatic color, White gives a very minimalist aesthetic and stylish look when used with the user interfaces websites, and mobile apps as well as clothing, making it a common choice in terms of favored color.

6 Conclusion and Future Work

The aim of the research paper was to determine the favored colors of the Indian users and the emotional association of these users to the selected major colors. After receiving 225 valid responses to the user survey, the results showcased that ***the colors—Black, Blue and White were the most preferred colors of the Indian users***.

For the emotional association section, it was found that there were deviations in Indian users' association to invoked emotions for four colors, viz. Blue, Orange, Brown and Grey.

In future, the results of this user survey with Indian users will be mainly used as reference, while designing the products, user interfaces and / or mobile apps targeting specifically the Indian Users. This research work will provide an idea to the designers about colors that are liked and preferred by the Indian people, while selecting the color schemes for the IT products, and even other applications. It may also help product designers or developers to influence the user's buying decisions and maximization of the product sale.

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Chapter 40
Quality Function Deployment: A Methodology for Testing Agriculture Sickle

Promilakrishna Chahal

1 Introduction

Agricultural hand tools design as the transformation of a concept into a product to satisfy farmers' needs while ensuring respect for the environment, legislation, and corporate profitability. The initial stage of an agricultural tool design process, therefore, involves identifying and formalizing various expectations of farmers (users) about the product to be designed, among are those relating to ergonomics features either explicitly or implicitly. The sickle is one of the oldest tools used in agriculture. Still widely used, it hasn't changed in design very much since time. Sickle are with two types of cutting edge, i.e., plain and serrated having a narrow serration with a depth of about 1 mm are being used at the farm by the farmers in the country. Of these, the use of plain sickle is more because serrated sickle is mostly preferred for wheat harvesting (Singh 2012). Design features of nine different types of sickles were analyzed and they indicated that blade geometry contributes significantly to human performance (Nag et al. 1988). Improved sickle with serrated edge reduced the drudgery of farm women by about 16.5% as compared to local sickle for harvesting wheat crop (Gite and Agarwal 2000). In India, regarding agriculture hand tools, there is no special design that has been developed for farm women who are doing a tremendous job in agriculture. Women are found to be engaged in agriculture farm activities with traditional old tools like sickle (Karunanithi and Tajuddin 2003). Less work is being reported on sickle design for especially farm women and its effect on women working conditions. There is a need to evaluate sickles and design them accordingly to users (farmers). For designing perspective quality function deployment methodology is the most reliable and used technique in designing agriculture hand tools as per customer needs (Akao 1993). In other words, it is a

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method for introducing quality right from the design stage to satisfy the customer and to transform customer requirements into design objectives and key points that will be required to ensure quality at the production stage**.** QFD methodology was used to design school furniture by defining the most important variables and characteristics of the final product based on the customers' voices. As a result, based on QFD and Ergonomics, the new designs were low maintenance, low cost, ergonomically correct, strong, and durable (Gonzalez et al. 2003). QFD technique reducing all risks of getting ergonomics-related problems and enhances customer-oriented design without ignoring ergonomics principles (Hashim et al. 2012; Powar et al. 2009). In this paper, we demonstrated how a specific design method, the quality function deployment (QFD), can be a vector for integrating ergonomics into the sickle design and, more generally, occupational risk prevention into work equipment design.

2 Methodology

A. *Data collection procedure*

This study used the survey method, which aim was to propose an improvement in the product design of sickle based on farm women's needs. Two resource centers were established in Mangali and Behbalpur villages (one in each) of Hisar District, where improved sickles were kept for use purposes of farm women. Two days training program was organized in each village where a demonstration on the use of sickle was given. After training 60 farm women (30 farm women from each village) were selected as respondents who were found to be working in farm activities on daily basis. The sickle was given to each farm woman for 30 days for use. A register was maintained in which issuing date, return date, and performance level of sickle from each respondent were recorded. A personal interview schedule was done with farm women to collect the data on the use and performance of sickle. Data were analyzed by using QFD methodology to evaluate the sickle performance (Table 1).

B. *Description of sickle*

The sickle used for research was developed by the Falcon industry. The below table gives a clear picture of the description of the sickle. As the table reflects that total length of the sickle was 40.5 cm with a weight of 230 g. The size of the blade and handle was 22.0 and 18.5 cm, respectively, with a handle diameter of 3.3 cm. The blade was found to serrate up to 0.4 cm with a conclave of the blade being 4.0 cm (Table 2).

C. *Quality function deployments methodology*

For the present study, the sickle was tested based on quality function deployment methodology. Quality Function Deployment (QFD) methodology was developed in 1966 by **Yoji Akao** in Japan. It was a structured methodology to translate the desires

Table 1 Data collection procedure

Establishment of Resource Centers	Hisar District, Haryana
Locale of Study	Mangali and Behbalpur villages
Selection of Respondents	60 Farm Women (30 from each village)
Variables and their Measurements	Demonstration and trainings on Agriculture Sickle
Collection of Data	Personal interview schedule
Analysis of Data	QFD Methodology

of the customer into product design. In this study, the researcher focused on 6 steps, to test the sickle. The step-wise description was as below:

Step (1) *Customer needs and their degrees of importance*: Farm women's requirements were gathered from surveys and interviews methods. Then the degree of importance of each need was identified by farm women.

Step (2) *Technical requirements and their interrelationships*: After listing the farm women's needs as customer needs and their degrees of importance, the technical requirements were established. Technical requirements are the translation of these needs into design requirements expressed in measurable attributes. The roof of the House of Quality (HOQ) was used to show the correlation between the technical requirements.

Step (3) *Relationships between customer needs and technical requirements*: This was the center of HOQ. The farm women needs that were listed on the left column were connected to the technical requirements listed across the top, and the correlation of each customer attribute with the technical requirement was analyzed by using the score of 9 (strong correlation), 3 (moderate correlation), 1 (weak correlation) and 0 (no correlation).

Step (4) *Competitive analysis*: Competitive analysis evaluated the sickle with other sickles available in the market. In this step, market sickles were reviewed in satisfying the farm women's needs shown in the rightmost columns. 1 to 5 scales, five being the best, were used in evaluating each competitor's product.

Step (5) *Importance ratings and concept selection*: This section completed the basement of the house where the importance ratings were recorded. The importance ratings were the relative weights of each technical requirement

Table 2 Particulars of studied sickle

Particulars	Dimensions of sickles (cm)
Sickle length	40.5
Maximum handle diameter	3.3
Size of sickle	22.0
Concavity of blade	4.0
Grip space	5.0
Maximum handle length	18.5
Effective handle length	17.0
Length of ferrule	1.8
Blade length	15.0
Serrated blade	0.4
Weight of sickle (g)	230

based on the weight of each item in terms of satisfying the farm women's needs.

Step (6) *Target values for technical requirements and to determine technical difficulties:* The requirements that corresponded to the needs of farm women and for the ones that have a higher degree of importance got more emphasis. Then, the technical difficulties were identified based on how difficult was to achieve the target values selected for each technical requirement. The rankings are done typically using a five-point scale with 1 being the easiest and 5 the most difficult.

3 Results

The present study was conducted on 60 farm women, out of the 40.0% women were found to be the age group of 31–42 years, followed by 38.3% who were from 43 to 54 years of age group and 21.7% farm women were in the ages between 19 and 30 years. Regarding education, nearly about one-third of the farm women (31.7%) were educated up to high school, followed by 18.3% educated up to secondary school and 15.0 and 13.3% were having education of primary and middle school, respectively. Besides this 21.7% of farm women were illiterate. The majority of the respondents/farm women (61.7%) were in a joint family. And more than fifty percent (53.3%) were in a family having 7–9 members. As per the use of sickle, maximum farm women (96.7%) were found to be using sickle on daily basis. Nearly about fifty percent (43.3%) were using sickle 1:00–1:30 h daily, followed by 38.3% using 1:30–2:00 h and 18.3% farm women were found to be using sickle for 0:30 min–1:00 h daily.

Use of Quality Function Deployment methodology for sickle testing

Testing of the sickle was done under 6 phases which were as below:

A. *Customer needs and their degrees of importance*:

The customers' attributes were (C_1) Good quality material, (C_2) proper size of the handle, (C_3) proper size of blade (C_4) grip, (C_5) low cost, (C_6) no maintenance required, (C_7) size of sickle, (C_8) lightweight of sickle, (C_9) no need to a sharp blade, and (C_{10}) not causing pain. Farm women assessed the attributes with the Likert scale method (1–5). The rating was done by women based on the weightage and importance of each attribute in the sickle design. As per finding, farm women gave maximum score (5) to grip, size of sickle and not causing pain when using followed by good quality material, the proper size of handle and blade, and lightweight of sickle got 4 score; and low cost, no maintenance required and no need to sharp blade attributes were having weighted means 3 (Table 3).

B. *Technical requirements and their interrelationships*

Attributes of technical response were taken from ISI sickle and experts in agriculture engineer. Attributes of technical requirements were (T_1) ergonomically designed, (T_2) standard size, (T_3) seriated blade, (T_4) made of cast iron, (T_5) strength, (T_6) standardized weight, (T_7) appropriate shape/size of the handle, (T_8) fixed joint, (T_9) appropriate shape/size of the blade, and (T_{10}) fit users. The next step is to identify the relevant interactions between each of the technical characteristics. In HOQ, the quantity was placed on the roof. By using the roof matrix, it was represented the interrelationship among the technical response. The correlation among technical attributes was studied and the score was given as highly strong (++), strong (+), neutral (). Negative (−), and highly negative (−) (Table 4).

Table 3 Customers need and their importance

Customer requirements	Code used for attribute	Weightage
Good quality material	C_1	4
The proper size of the handle	C_2	4
The proper size of the blade	C_3	4
Grip	C_4	5
Low cost	C_5	3
No maintenance required	C_6	3
Size of sickle	C_7	5
Lightweight of sickle	C_8	4
No need for a sharp blade	C_9	3
Not cause pain	C_{10}	5

Table 4 Technical attributes of sickle

Attributes	Code used for attribute
Ergonomically designed	T_1
Standard size	T_2
Serrated blade	T_3
Made of cast iron	T_4
Strength	T_5
Standardized weight	T_6
Appropriate shape/size of the handle	T_7
Fixed joint	T_8
Appropriate shape/size of the blade	T_9
Fit to users	T_{10}

C. *Relationships between customer needs and technical requirements*:

To determine the relationship matrix of attributes, customer requirements attributes are placed on the vertical edge on the left side, while the technical characteristics are laid out in the horizontal section at the top edge. The relationship between customer requirements and technical requirements was determined based on an appropriate scale of 9–3–1–0 which represented the strong, medium, weak, and no relationship among attributes. The below table shows the relationship of each customer attributes with technical requirements. Each correlation value in the table was multiplied with the weightage of customer importance and then all scores were added to find out the importance weighting of each technical point. Findings in the table revealed that maximum importance weightage ($\overline{x} = 198$) was received by T_7 (appropriate size of handle) and T_9 (appropriate size of the blade), followed by T_1 (ergonomically design)

Table 5 Relationship matrix between customers' need and technical attributes

CR	TR									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
C1	9	–	3	9	9	3	–	9	–	9
C2	3	9	–	–	–	3	9	–	9	–
C3	3	9	1	9	–	3	9	–	9	–
C4	9	1	–	–	3	3	9	3	9	–
C5	–	–	3	3	–		–	–	–	3
C6	–	–	9	9	9	1	–	9	–	1
C7	9	9	–	–	1	9	9	3	9	–
C8	9	3	–	1	3	9	–	1	–	–
C9	1	–	9	3	3		–	–	–	–
C10	9	3	9	3	3	3	9	9	9	–
IW	189	149	124	136	119	150	198	142	198	48
RIW	7.68	9.75	11.71	10.68	12.2	9.68	7.33	10.23	7.33	30.2

CR: Customer requirement; TR: technical attributes; IW: importance weightage and RIW; relative importance weightage

which got the score of $\overline{x} = 189$ and T6 (standardized weight) and T_2 (standard size) got weighted means of $\overline{x} = 150$ and $\overline{x} = 149$, respectively (Table 5).

D. *Competitive analysis*:

In this step, competitors' sickles available in the market were reviewed because of satisfying the customers' needs shown in the rightmost two columns of the matrix. We used 1 to 5 scales, 5 being the best, were used in evaluating each competitor's product. The improved sickle was compared with other sickles available in the market. Data in the table unveil that improved sickle was found to be more satisfactory on quality of material (C_1), no maintenance required (C_6), and no need to sharp blade (C_9) with highest weighted mean score ($\overline{x} = 5$). Data in line represent that improved sickle was not found to be fit for users regarding size and shape of handle and blade which required immediate improvement (Table 6).

E. *Importance ratings and concept selection*:

Value for the importance was estimated by calculating the total weight for each relationship between product attributes and technical response. Data revealed that maximum interest of farm women was found in ergonomic design of sickle (52) followed by appropriate size of the handle (45) and blade (45). Different concepts were determined and ranks were given based on excellent, best, and worst with a score of 2.0, 1.0, and −1.0, respectively. The concept based on users' anthropometry was found to be excellent in correlation with T_1, T_6, T_7, T_9, and T_{10}. Regarding light in weight, T_7, T_9, and T_{10} were found correlated, and the same result was found for the standardized weight of sickle (Tables 7 and 8).

Table 6 Comparison of studied sickle with other sickles available in market

Our product	Competitor A	Competitor B
5	4	4
3	3	5
3	3	4
4	3	3
4	3	3
5	3	2
4	3	4
4	4	3
5	2	1
2	2	2

Table 7 Level of interest in each technical attribute

Technical requirements	Importance
Ergonomically designed	52
Standard size	34
Serrated blade	34
Made of cast iron	37
Strength	31
Standardized weight	34
Appropriate shape/size of the handle	45
Fixed joint	31
Appropriate shape/size of the blade	45
Fit to users	13

Table 8 Selection of concept based on attributes

Concept selection	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Based on users' anthropometry	*	–	+	–	–	*	*	–	*	*
Light in weight	–	+	–	–	–	–	*	+	*	*
For both hands	*	–	–	–	–	–	*	–	*	+
Standardized shape	*	=	–	–	–	+	*	–	*	*

F. *Target values for technical requirements and to determine technical difficulties*:

They are determined from the relationship of the technical response. The calculation was performed by translating all weight values of the relationship and dividing the weight of each technical response by the total weight. Furthermore, the level of difficulty (on a scale of 1 to 9) was given based on the range of percentage.

Table 9 Level of difficulties in each technical attribute

Technical requirements	Difficulty
Ergonomically designed	3
Standard size	3
Serrated blade	4
Made of cast iron	3
Strength	4
Standardized weight	3
Appropriate shape/size of the handle	3
Fixed joint	3
Appropriate shape/size of the blade	3
Fit to users	9

(a) 0–5% level of difficulty = 1
(b) 6–11% level of difficulty = 3
(c) 12–17% level of difficulty = 5
(d) 18–23% level of difficulty= 7
(e) >24% level of difficulty= 9

Based on these scores, maximum problems were, fit to users attributes (9), followed by strength (4) and seriated blade (4) which represented that these components should be redesigned as per customers' perception (Table 9).

Overall six target values; 35 cm length of sickle, seriated blade thickness up to 2 ± 0.5 cm, the standard weight of 210 g, size of handle 11 ± 2, size of handle 15 ± 2 and Handle diameter of 3 ± 0.2 cm with grip space 3.5 ± 0.2 cm were decided for improving the design of sickle as per customers' requirements (Table 10).

4 Conclusion

The working and living conditions of female agricultural workers are underprivileged all over India. Heavy physical work, inadequate working methods, working techniques, and tools not only cause unnecessary fatigue and occupational accidents but also leads to low productivity. As per the present study, the product design of sickle was found satisfactory for male farmers, but as per female farmers, no specific design/concept has been corporate by the designer. Women farmers represent more than a quarter of the world's population. Women comprise, on average, 43% of the agricultural workforce in developing countries. Farm women were not found satisfied with the agriculture sickle as it was not as per their requirements. The use of sickle was causing muscle strain, ache in hands, and also reducing their productively on work. They were found to be managing with a sickle for most of the time during agriculture work. This was making them frustrated and less interested in the task. Some of the crucial factors for poor productivity were the use of local artisans made

Table 10 Target value for designing sickle for farm women

Particulars	Dimensions of studied sickles (cm)	Required dimension of sickle
Sickle length	40.5	35.0
Maximum handle diameter	3.3	3 ± 0.2
Size of sickle	22.0	17 ± 2
Concavity of blade	4.0	5 ± 1
Grip space	5.0	3.5 ± 0.5
Maximum handle length	18.5	11 ± 2
Effective handle length	17.0	13 ± 2
Length of ferrule	1.8	1 ± 0.2
Blade length	15.0	15 ± 2
Serrated blade	0.4	0.2 ± 0.5
Weight of sickle (g)	230.0	210 ± 10

tools/equipment; imported tools/ equipment which are not suitable for targeted user's physical capacity; anthropometric data are not taken into considerations for tools/ equipment design (Table 11) (Patel 2017).

The use of proper tools provides promising and encouraging results and hence it becomes utmost necessary to consider the human factors in the design of farm tools to enhance the operating efficiencies, working comforts, and thereby improving the productivity of workers. Ergonomically designed equipment/products enhance the human operating efficiencies and comforts during its operation (Kamate and Kumar 2015). As agriculture work is only considered a male-dominated task while most the of labor-intensive tasks of agriculture are done by women, but there are no specific tools/equipment that has been designed as per women anthropometry dimensions. The era of agriculture has been changing over time, and time demands to incorporate women prospective in agriculture engineering. So, suitable technologies have to be delivered to the farm women for raising farm productivity and empowerment (Patil and Babus 2018).

Table 11 Evaluation of agriculture sickle based on QFD methodology

Customer requirements	Weight age	↑ T1	↓ T2	x T3	↑ T4	↑ T5	↓ T6	↓ T7	x T8	↓ T9	↑ T10	Our product	Competitor A	Competitor B
		Technical requirements										**Competitor comparison**		
C1		●		○	●	●	○		●		●	5	4	4
C2		○	●				○	●		●		3	3	5
C3		○	●	Δ	●		○	●		●		3	3	4
C4		●	Δ			○	○	●	○	●		4	3	3
C5				○	○						○	4	3	3
C6				●	●	●	Δ		●		Δ	5	3	2
C7		●	●			Δ	●	●	○	●		4	3	4
C8		●	○		Δ	○	●		1			4	4	3
C9		Δ		●	○	○						5	2	1
C10		●	○	●	○	○	○	●	●	●		2	2	2
Importance weighting		189	149	124	136	119	150	198	142	198	48			
Relative Importance weighting		7.6	9.7	11.7	10.6	12.2	9.6	7.3	10.2	7.3	30.2			
Level of difficulty (%)														
Degree of importance (%)														
Concept selection														
Based on users' anthropometry		*	-	+	-	-	*	*	-	*	*			
Light in weight		-	+	-	-	-	-	*	+	*	*			
For both hands		*	-	-	-	-	-	*	-	*	+			
Shape as per users		*	=	-	-	-	+	*	-	*	*			

Improvement direction		
Maximum	↑	1.0
Target	x	0.0
Minimum	↓	-1.0

Concept selection		
Excellent	*	2.0
Best	+	1.0
Worst	-	-

Correlation		
Strong	●	9.0
Moderate	○	3.0
Week	Δ	1.0

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Chapter 41
Relationship of Pain in the Lower Back and Knee with Gender, Age, and BMI of the Pharmaceutical Supply Chain Workers

Pallavi Murarka and Manjit Kaur Chauhan

1 Introduction

"Musculoskeletal Disorders (MSD) are injuries and disorders that affect the human body's movement or musculoskeletal system (i.e. muscles, tendons, ligaments, nerves, discs, blood vessels, etc.)" (http://ergo-plus.com/musculoskeletal-disorders-msd/). And, work-related musculoskeletal disorders (WMSDs) are the musculoskeletal disorders that arise from activities such as bending, straightening, gripping, holding, twisting, clenching, and reaching. What makes these postures more harmful at workplace is the constant repetition and the long time spent in those postures (https://www.ccohs.ca/oshanswers/diseases/rmirsi.html). It was found out that 20.33, 34.33, and 45.32% of the workers were under high, medium, and low risk of MSDs, respectively, in a study of the work of 102 workers in a forging industry (Singh et al. 2012). Small-scale industries are important to the economy in countries like India and constitute a large workforce, but hardly any attention is given to the workplace design and postures adopted by the workers in these industries, which lead to WMSD among them (Mali and Vyavahare 2015; Sain and Meena 2016). It was found that 59.4% of workers from 60 small- and medium-sized factories reported musculoskeletal disorders in different body parts depending upon the type of industry they belonged to Joshi et al. (2001)

Workers in supply chain units of the pharmaceutical industry are involved in picking and packing medicines, and it requires them to walk, bend while sitting and standing, kneeling on the floor, and squat too often. Packing activities being static as well as repetitive demand fixed position and continued repetition of movements

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or both (Velaga and Telaprolu 2013). In the same study of pharmaceutical packing workers, the pain was reported to be 74% in the upper limb, 59.3% in the back, and 60% in the lower limb (Velaga and Telaprolu 2013). There was 36.8% incidence of back and spinal disorders were reported in a study of pharmacy packaging workers (Varmazyar et al. 2009). Prevalence of musculoskeletal disorders in the upper back, wrists/hands, low back, knees, neck, and shoulders symptoms were found to be the most common problems among packing workers (Pourmahabadian et al. 2008).

Canadian Centre of Occupational Health and Safety suggests that "hazards are best eliminated at the source; prevention strategies involving workplace layout, tool, and equipment design, and work practices should be considered" (https://www.ccohs.ca/oshanswers/diseases/rmirsi.html). Stooping and squatting squat sitting postures were the dominating postures in potato cultivation jobs. It was noted that the most affected body parts were the lower back (92.26%), the highest for all the activities (Pal et al. 2015).

A significant association between the gender of workers and self-reported musculoskeletal disorders was detected but not between the age of the workers and musculoskeletal disorders (Pourmahabadian et al. 2008). In another study of working conditions of pharmaceutical packing workers, pain in the neck, shoulder, and back was found to be related to the gender of the works, but the pain in low back wasn't (Kheiri et al. 2011–2012). Body Mass Index (BMI) of workers was found to be associated with the prevalence of MSD symptoms. However, this association was subject to the workers' physical workload (Viester et al. 2013).

The objective of this paper is to investigate if factors such as gender, age, and body mass index (BMI) of workers affect the presence of pain in the lower back and knee among workers of the pharmaceutical supply chain.

2 Methodology

2.1 Sample

A sample of 116 workers (91 male and 25 female) was chosen from 11 pharmaceutical supply chain units from India. The age of workers was 18–42 years, and the work experience was 1–15 years.

2.2 Tasks Performed by the Workers

As shown in Fig. 1, the main job of the workers at the distribution unit is to pick medicines from different parts of the godown, assemble them in one place, and pack them into customized packages for supply. The activities done by the workers to do this job include standing with bent back and legs, walking with load, and sitting in

Fig. 1 Main activities performed by the workers at distribution units in pharmaceutical supply chain

squatting and kneeling on the floor to pack medicines. The postures adopted while doing these activities are standing, standing with one or both legs bent, standing and sitting with bent and twisted back, squatting, and kneeling on the floor.

Observation of tasks performed by workers was done, and video recording and pictures were taken using a DSLR (Digital Single Lens Reflect) camera. Videos and photographs were then transferred to a computer for further evaluation.

2.3 Measurement of Pain, Demographic Details, and Anthropometric Measurements

Respondents were asked to mark body regions where they experience pain out of the nine anatomical regions prone to develop MSD. Nine anatomical areas are neck, shoulder, elbow, wrist/hand, upper back, lower back, hips/thighs/buttocks, knees, and ankles/feet (Kuorinka et al. 1987). A general questionnaire was used to collect the demographic data, and a weighing scale and anthropometric kit, and measuring tape were used to take anthropometric measurements.

Body Mass Index (BMI) of workers was calculated using the following formula:

$$\text{BMI} = \text{Mass/Square of Height} \quad (1)$$

Mass (in kilogram).

Height (in meters)

2.4 Analysis

Workers were classified into three BMI classes and three age groups. Table 1 shows

Table 1 Count and percentage of workers in each BMI and age group

BMI groups				
	13.2–18.5	18.6–24.5	24.6–30.6	Total
Count	17	80	19	116
% within each group	14.7%	69%	16.3%	100.0%
Age groups (Years)				
	18–25	26–34	35–42	Total
Count	40	50	26	116
% within each group	34.5%	43%	22.5%	100.0%

the count and percentage of workers in each category of BMI and age. The distribution of workers in the categories of BMI and age is also represented in Figs. 2 and 3.

Chi-square test with a 0.05 level of significance was used to determine the association of pain in body parts with gender, body mass index, and age of workers. SPSS software was used to do statistical analysis.

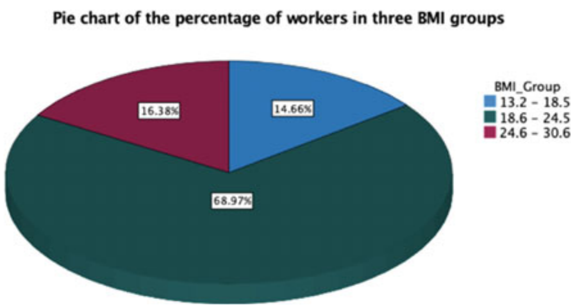

Fig. 2 Percentage of workers in three BMI groups

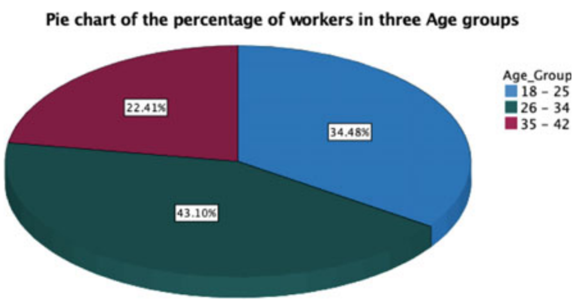

Fig. 3 Percentage of workers in three age groups

Table 2 Mean age, years of work experience, education, monthly income, and BMI of workers

Parameter	Mean ± SD (Total)	Range	Mean ± SD (Male workers)	Mean ± SD (Female workers)
Age (Yr.)	28.29 ± 6.15	18–42	26.87 ± 5.3	33.48 ± 6.41
Work experience (Yr.)	4.30 ± 3.44	1–15	4.41 ± 3.5	3.88 ± 3.3
Education (Yr.)	11.66 ± 2	3–17	11.82 ± 2	11.08 ± 2
Monthly income	9,688.79 ± 3923.44	3000–23,000	10,765.93 ± 3714.2	5,768.00 ± 1270.73
BMI	21.94 ± 3.07	13.24–30.6	21.83 ± 3.0	22.35 ± 3.3

3 Result

3.1 *Subject Demographic Information*

Table 2 presents the characteristics of the sample.

3.2 *Presence of Pain in Lower Back and Knee*

73 people (63%) and 37 people (32%) reported the presence of pain in the lower back and knee, respectively. Table 3 shows the frequency and frequency percentage of pain reported by both the genders separately and also, by the total number of respondents.

No significant association (p-value = 0.73) was found between the presence of pain in lower back and gender of the workers.

However, a significant association (p-value = 0.015) was found between the presence of pain in knee and gender of the workers.

Table 3 Frequency and percentage of workers with pain in low back and knee in gender categories

		Female	Male	Total
Pain in lower back	Count	15	58	73
	% within gender	60.0%	63.7%	62.9%
Pain in knee	Count	13	24	37
	% within gender	52.0%	26.4%	31.9%

3.3 *Association Between Pain and BMI Levels*

No significant association was found between the presence of pain in the lower back and BMI of workers, and pain in the knee and BMI of workers (*p*-value 0.726 and 0.87, respectively). Table 4 shows the frequency and frequency percentage of pain reported by each BMI group. Figure 4 shows the percentage of workers reporting pain in the lower back and knee in three categories of BMI.

Table 4 Frequency and percentage of workers with no pain and pain in low back and knee in BMI groups

			≤18.5	18.6–24.5	24.6+	Total
Pain in lower back	No	Count	5	30	8	43
		% within BMI group	29.4%	37.5%	42.1%	37.1%
	Yes	Count	12	50	11	73
		% within BMI group	70.6%	62.5%	57.9%	62.9%
Total		Count	17	80	19	116
		% within BMI group	100.0%	100.0%	100.0%	100.0%
Pain in knee	No	Count	12	55	12	79
		% within BMI group	70.6%	68.8%	63.2%	68.1%
	Yes	Count	5	25	7	37
		% within BMI group	29.4%	31.3%	36.8%	31.9%
Total		Count	17	80	19	116
		% within BMI group	100.0%	100.0%	100.0%	100.0%

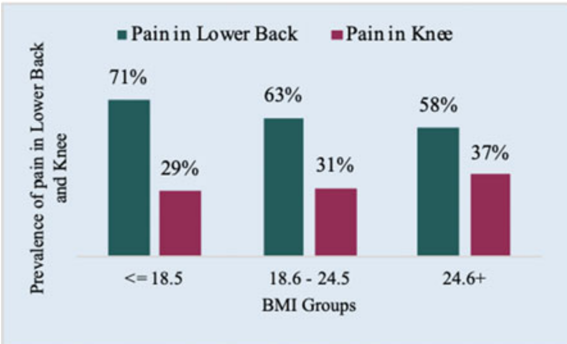

Fig. 4 Bar chart for percentage of prevalence of pain in lower back and knee for each BMI group

3.4 Association Between Pain and Age Groups

No significant association was found between the presence of pain in lower back and age group, and presence of pain in knee and age group of the workers (p-value 0.817 and 0.735, respectively). Table 5 shows the frequency and frequency percentage of pain reported by each age group. Figure 5 presents the percentage of workers who reported pain in the lower back and knee in three categories of age.

Table 5 Frequency and percentage of workers with no pain and pain in low back and knee in age groups

			≤25	26–34	35+	Total
Pain in lower back	No	Count	14	18	11	43
		% within age group	35.0%	36.0%	42.3%	37.1%
	Yes	Count	26	32	15	73
		% within age group	65.0%	64.0%	57.7%	62.9%
Total		Count	40	50	26	116
		% within age group	100.0%	100.0%	100.0%	100.0%
Pain in knee	No	Count	26	36	17	79
		% within age group	65.0%	72.0%	65.4%	68.1%
	Yes	Count	14	14	9	37
		% within age group	35.0%	28.0%	34.6%	31.9%
Total		Count	40	50	26	116
		% within age group	100.0%	100.0%	100.0%	100.0%

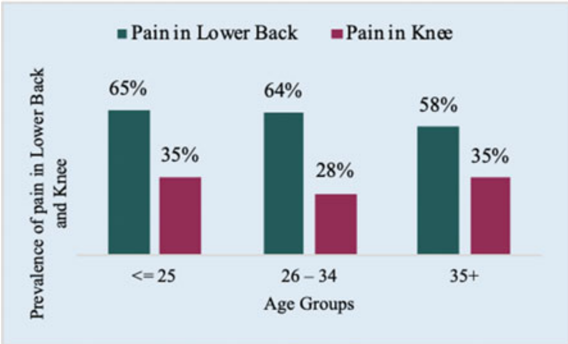

Fig. 5 Bar chart for percentage of prevalence of pain in lower back and knee for each age group

3.5 Results of Non-parametric Test

The prevalence of pain in the lower back and knee was the same across three BMI groups with *p*-values of 0.72 and 0.87, respectively. So was the prevalence of pain in the lower back and knee across three age groups with p-values of 0.81 and 0.74 each. The presence of pain in the lower back was identical for both genders ($p = 0.73$). Whereas, it was not identical for pain in the knee in male and female workers ($p = 0.015$). The significance level was 0.05.

4 Discussion

The prevalence of pain in the lower back and knee, respectively, is reported to be 63 and 32% in this study. Similar findings were seen in previous studies: 44.7% knee pain and 36.8% back pain were reported by pharmacy packing workers in a study in Iran (Varmazyar et al. 2009), and 47% low back pain and 43% knee pain were reported by pharmacy packing workers in another study (Pourmahabadian et al. 2008). For the workers of a tobacco factory who had to bend and stand with the flexed legs frequently, the prevalence of MSD in the low back (55%) and knees (45%) was noticed (Etemadinezhad et al. 2013).

Results of this study revealed that pain in the lower back and knee was the same across all categories of age and BMI level of workers. Pain in the lower back showed no dependence on the gender of the worker in this study, and this result was in agreement with a previous study where no relationship between pain in the low back and gender of packing workers was seen (Pourmahabadian et al. 2008, Viester et al. 2013). However, pain in the knee showed a dependence on the gender of the worker in this study. The results from the current investigation indicate that the presence of MSD symptoms could be related to the postures employed for the work of the supply of medicines. Former researches that are done on pharmaceutical packing workers explain the presence of musculoskeletal disorders, the need for posture correction, and a call for ergonomic intervention in the workplace. However, no work has been done on the posture, work pattern, and workplace of the workers in the pharmaceutical supply chain system. There is a scope to create a workstation design that can help in lessening the MSD symptoms in these workers.

The final RULA score (mean 4.87) emphasize on poor workstation design among pharmacy packaging workers (Varmazyar et al. 2009).

5 Conclusion

The relationship between pain in body parts and demographic factors such as age, gender, and BMI could not be established decisively. The prominence of pain in the lower back and knee among workers of pharmaceutical supply chain units suggests that ergonomic evaluation work postures of pharmaceutical supply chain workers need to be done. There is also a scope of ergonomic intervention at work place to reduce musculoskeletal discomfort as no workplace has been designed for the pharmaceutical supply chain workers.

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Chapter 42
Vibration Exposure Analysis Among Two-Wheeler Riders in Kerala

Mathew John, Jithu Gopinath, and S. A. Binoosh

1 Introduction

Two-wheelers are prominently used for public transport in urban, suburban and rural areas of India. In Kerala, around 64% of total vehicle is two-wheelers (Ministry of Statistics and Programme Implementation 2017). This shows the importance of two-wheelers in transportation sector of Kerala. Two-wheeler riders are exposed to several occupational health hazards during their riding. These hazards include vibration exposures, repetitive strain injuries, improper ergonomic postures, toxic pollutant gases, harmful radiations, noise pollutions. Two-wheeler riders spend a significant fraction of their riding time under exposure to vibration along with improper posture. It will affect the health as well as productivity of these riders. Common disorder among riders during vibration exposure includes spinal disorders, auditory and visual impairments and neurovascular disorders.

Roseiro et al. (2016) proposed that vibration exposure in automobile operators can be classified into hand arm vibration (HAV) and whole-body vibration (WBV). WBVs are transmitted from the source to the operator body through seat or feet or both, when operating an automobile. It is also transmitted when standing on vibrating floors such as automobile body floor. WBV exposures are characterized by high amplitude and low frequency and lies in the range of 1–20 Hz. HAVs are transmitted to the body through hands and arms of the operator and lies in the frequency range of 6.3–1250 Hz. Vibration exposures are influenced by irregularities in road surface, suspension type in the vehicle, presence of pillion riders and personal characteristics of the riders.

Kharat and Dhande (2015) studied the effect of WBV exposure on three-wheeler riders due to irregular surfaces, different engine and vehicle conditions. The result

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showed an increase in magnitude of vibration exposure on operator as road condition varied from smooth to rough conditions. This shows the influence of road condition on WBV exposure. Malchaire et al. (1996) studied the effect of pavement condition, seat condition and load condition on vibration exposure on fork-lift operators. The results showed significant relationship between vibration exposure and the parameters considered which are load on the vehicle, pavement condition and characteristics of driver and vehicles.

Griffin (1990) had defined the overall response of human body to vibration exposure into five effects. It includes general discomfort, lower productivity, health disorders, motion-sickness and inability to percept lower magnitude of vibrations. Piligian et al. (2000) reported that operators involved in occupations involving prolonged forceful exertions combined with improper ergonomic posture and vibration exposures are more susceptible to musculoskeletal disorders (MSDs) and the severity can be reduced by implementing certain ergonomic interventions at organizational or technological level. Various authors reported that motor vehicle drivers have higher chance for occurrence of MSDs in distal upper extremities and vertebral column due to vibration exposure and postural stresses (Grace and Peggo 2017; Anoop and Binoosh 2019). Ramasamy et al. (2017) have concluded that prolonged usage of two-wheeler can cause driving-related musculoskeletal disorders (DMSDs) in lower back and distal upper extremities (wrist and hands). Common DMSDs are lower back pain, visual and auditory impairment and peripheral nervous system disorders (Roseiro et al. 2016; Anoop and Binoosh 2019). Many authors reported that cause and effect relationship existing between hand arm vibration exposure and MSDs in finger, wrists is commonly known as hand arm vibration syndrome (HAVS) (Azmir et al. 2015; Roseiro et al. 2018; Xueyan et al. 2016). HAVS are commonly vascular and neurological disorders which include tingling sensation finger digits, wrist/hand inflammation, intolerance to cold temperatures and strophic skin lesions of the fingers. These symptoms are influenced by factors such as source or equipment type, job nature and duration as well as intensity of vibration exposure. Singh (2019) stated that exposure to WBV along with improper ergonomic posture can have deteriorating effect on intervertebral disc regions. The study revealed that workers or operators at younger age are more susceptible to lower back disorders due to WBV.

From the literature, it is evident that the risk assessment of HAV and WBV exposure should be done for proper evaluation. Risk assessment of both HAV and WBV exposure can be done by subjective or objective method. Subjective method is a type of qualitative risk assessment using questionnaires such as standard Nordic questionnaire. Objective methods assess exposure risk quantitatively by on-site observation of work. For this, International Organization for standardization (ISO) has proposed certain guidelines for quantitative measurement of vibration exposure. Literature review have revealed that majority of authors have used ISO 2631 for risk assessment of mechanical vibration exposure to human body (WBV) and ISO 5349 for risk assessment of mechanical vibration exposure to hand arm system (HAV) of workers (Roseiro et al. 2018; Singh 2019). The literature also explains the standard limit values set by European directive 2002/44/EC regarding vibration exposure to control the severity of both HAV and WBV exposures. These are provided to assess daily limit values to the exposure values of the operators at workplace.

The objective of the study was to quantify HAV and WBV exposure among two-wheeler riders in Kerala, when riding through different road condition with different suspension type vehicles (mono shock/dual shock). The study also explored the effect of pillion rider on vibration exposure in main rider. Time duration (in years) required for developing HAVS in these riders were also determined by quantifying HAV exposure.

2 Method

The study was carried out in two stages. A primary qualitative risk assessment was conducted using modified Nordic questionnaire to identify the body parts which were affected by vibration exposure. Odd ratio test was used as a measure of association between an exposure (vibration exposure) and an outcome (MSDs). Subsequently, quantitative risk assessment was conducted with an experimental setup using accelerometers and an Arduino-based data acquisition system. The experiment was conducted as per the guidelines set by ISO standard for HAV and WBV.

2.1 Qualitative Risk Assessment

Qualitative risk assessment was conducted using modified Nordic questionnaire. The questionnaire consists of general questionnaire part for collecting basic details of the participants and MSD specific questions. A marked body map is also provided along with second part of the questionnaire for easy completion. The data were collected from 133 participants by providing the questionnaire in online and offline modes. The sample size required for the study was calculated using Cochran's formula (Cochran 1977). The sample size was within a margin of error of 8% and confidence interval of 95%. Odd ratio test was done using the data obtained from the questionnaires. Odd ratio test is conducted to check the association between the outcomes of an event. The test is applicable when the point of interest of the study is to compare the relative odds of the outcome.

2.2 Quantitative Risk Assessment

The study used the guidelines and calculation method mentioned in ISO 5349 for HAV and ISO 2631 for WBV. Vibration exposure levels of common 150 cc mono shock and dual shock bikes were evaluated based on the standard values provided by EU directives 2002/44/EC (ISO 2631-1 1997; ISO 5349-1 2001; ISO 5349-2 2002).

The experiment was performed at two road conditions of smooth and rough road combined with the conditions of pillion rider, i.e., pillion rider present and absent. The data were collected based on the combination of all three conditions above mentioned at an average speed of 45 km/h. The two-wheelers were driven by 30 non-professional bike riders for data collection. Five of them were selected as pillion rider subjects for the purpose of the study.

2.3 Vibration Exposure Calculation

European directive 2002/44/EC standardized the risk assessment of exposure level to HAV on ISO standard 5349 and to WBV on ISO standard 2631. These standards normalize the daily exposure values of HAV and WBV based on the RMS value of acceleration in three axes to an 8 h reference period parameter $A(8)$ (ISO 2631-1 1997; ISO 5349-1 2001; ISO 5349-2 2002).

Similarly, these standards can be used to determine the total magnitude of the vibration for both HAV and WBV exposures based on the acceleration value in three coordinate axes.

The duration of occurrence of HAVS or white fingers disease is given by the relationship between the parameter values of $A(8)$ and the number of year's exposure (D_{y}), as in

$$D_y = 3.1 \times [A\,(8)]^{-1.06} \tag{1}$$

2.4 Vibration Exposure Measurement

Vibration and mechanical shock levels were calculated for 15-min duration under stipulated conditions and were measured based on the guidelines set by the standardized ISO standards (ISO 2631 and ISO 5349). For data collection, two tri-axial accelerometers were incorporated with an Arduino-based Data Acquisition (DAQ) system.

First accelerometer was attached in the handle bar for measuring HAV and second accelerometer was placed in the seat where main rider sits as shown in Fig. 1. Accelerometer ADXL335 works on a voltage of 3.3 V. For proper operation of accelerometers, analog reference voltage (AREF) of Arduino board is connected to 5 V port. The grounds of the two accelerometers were connected to the common point in the bread board.

In the first accelerometer, x-, y- and z-axis terminals were connected to the A0, A1 and A2 ports in the Arduino board, respectively (Fig. 2). Similarly, in second accelerometer the x-, y- and z-axis terminals were connected to the A5, A4 and A3 ports of the Arduino board, respectively. The ports and terminals were connected

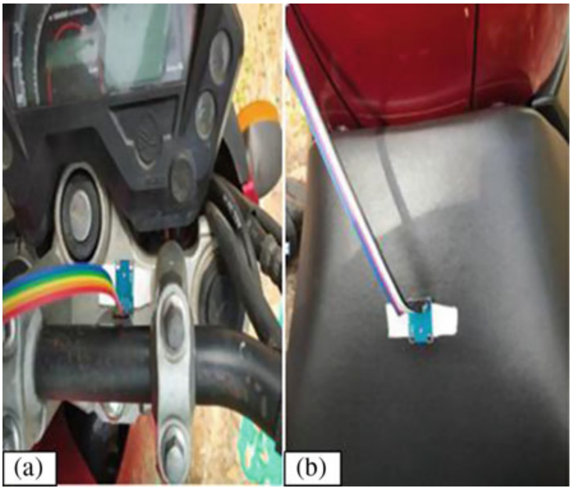

Fig. 1 Location of accelerometers; **a** fixed in handle for HAV measurement and **b** fixed on seat for WBV measurement

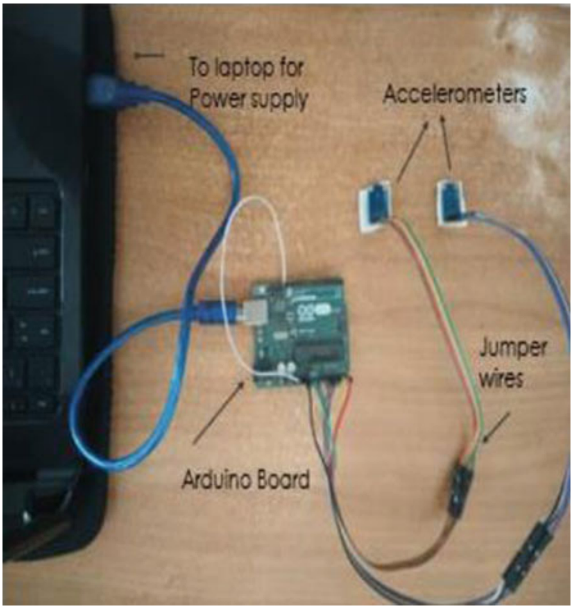

Fig. 2 Experimental setup for measuring the vibration exposure

using jumper wires. The accelerometer placed at handle bar and seat was aligned in a manner that x is the posterior direction, y is the media lateral direction and z is the superior and inferior direction.

3 Results

3.1 Qualitative Risk Assessment

The data collected from the participants using modified Nordic questionnaire have been tabulated. The age of respondents varied from 18 to 43 years. Average age of the participants showed a value of 23.84 years with a standard deviation of 3.26. The weight of the participants varied from 40 to 92 kgs. Their height varied from 150 to 186 cm. The weight and height of the participants indicated an average value of 69.12 kgs and 171.58 s cm, respectively. The total number of subjects participated in the study were divided into two categories. Class A category consists of riders who reported discomfort due to vibration exposure during their riding. Class B consists of riders who reported no problem due to vibration exposure. Class A consists of 89 participants and Class B consists of 44 participants. This comes to about 67% Class A category and 33% of Class B category. All participants have reported that they had discomfort due to vibration exposure and they have DMSDs due to this exposure. The subjects reported that trouble experienced during last 12 months were higher for lower back (63.9%) followed by hands (48.1%), upper back (36.8%), neck (37.6%) and shoulders (30.8%). Majority of respondents have responded that trouble in lower back (43.6%) have affected their productivity. This is followed by trouble in hands (24%), neck (21%), upper back (18.8%) and shoulder (14.3%).

It was seen 40.6% of subjects responded that they had trouble in lower back during last 7 days. Other body parts where subjects felt pain and discomfort during last 7 days were neck (20.3%) followed by hands (19.5%) and upper back (18%). As per the responses from the subjects, elbows and wrist/hands of the subjects are mostly injured due to accidents. This accounts to 21% and 18% of the subjects, respectively. This is followed by injuries in knees (12.8%) and ankles (10.5%) due to accidents. Injuries due to accidents in other body parts are negligible compared to these values.

All subjects responded that they had trouble in all body parts for duration of 1–7 days. The duration of pain and trouble in neck, hands, upper and lower backs and shoulders were consistent. 68.8% of the subjects have visited health professionals for pain in lower back. 35.4% of subjects visited for upper back, 25% for shoulders and 20.8% for neck problems. The result from qualitative test indicate that upper back, lower back, neck and wrist/ hands of the two-wheeler riders are more susceptible to DMSDs.

Odd ratio test was conducted to determine whether vibration exposure acts as a risk factor for DMSDs in two-wheeler riders. It was also used to compare the magnitude of mono shock and dual shock as a risk factor for occurrence of DMSDs in these riders. The accuracy of odd ratio test depends on the p value. The value below 5% ($p < 0.05$) was considered as significant for association between the factors under study. Odd ratio test was conducted using SPSS software.

Table 1 indicates the odd ratio test conducted for determining the magnitude of DMSDs in different body parts due to the usage of mono shock and dual shock bikes. From the results, a significant ($p < 0.05$) association of DMSDs is observed

Table 1 Odd ratio of DMSD and suspension type

Body regions	Suspension type		Odd ratio	CI (95%)	*p* value
	Dual shock	Mono shock			
Neck	25	18	0.785	0.340–1.815	0.572
Shoulders	16	17	1.524	0.641–3.623	0.339
Elbows	17	17	1.391	0.589–3.287	0.451
Wrists/Hands	36	28	0.843	0.333–2.129	0.717
Upper back	29	20	0.690	0.297–1.600	0.386
Lower back	48	33	0.201	0.039–1.027	0.037
Hips/Thighs	21	7	0.283	0.105–0.763	0.010
Knees	5	3	0.714	0.160–3.187	0.657
Ankles/Feet	11	9	1.003	0.369–2.728	0.995

Table 2 Odd ratio of DMSD and vibration exposure category

Body regions	Class A	Class B	Odd ratio	CI (95%)	*p* value
Neck	33	10	2.004	0.877–4.576	0.096
Shoulders	25	8	1.758	0.718–4.301	0.213
Elbows	30	4	5.085	1.663–15.550	0.002
Wrists/Hands	50	14	2.747	1.285–5.875	0.008
Upper back	43	6	5.920	2.276–15.402	0.000
Lower back	72	18	6.118	2.748–13.619	0.000
Hips/Thighs	22	6	2.080	0.775–5.577	0.140
Knees	7	1	3.671	0.437–30.813	0.202
Ankles/Feet	13	7	0.904	0.333–2.456	0.843

in lower back and hips/thighs. Hence, it can be inferred that riders using dual shock suspension bikes have higher chance for occurrence of DMSDs in lower back and hips/thighs compared to riders using mono shock vehicles.

Table 2 indicates the odd ratio test conducted for determining the association between DMSDs in different body parts due to vibration exposure. The results indicate a significant ($p < 0.05$) association for elbows, wrists, upper back and lower back. Hence, riders who are exposed to vibration during bike riding are susceptible to DMSDs occurring in body parts such as distal upper extremities and lower back.

3.2 *Quantitative Risk Assessment*

Quantitative risk assessment was carried out using accelerometer and Arduino-based data acquisition system as per ISO guidelines. The exposure data obtained were analyzed with the standard limit values set by European Directive 2002/44/EC. State highway 1 (Adoor–Enathu) were selected for data collection for smooth road condition. Similarly, Grama panchayath road between Enathu and Pathanapuram were selected for the rough road condition. Data were collected under the combination of three conditions for both HAV and WBV. Then obtained dataset was assessed in accordance to EU directive standards.

3.3 Variation of WBV with Different Parameters

For WBV exposure, ISO 2631 standard was used for measurement as well as assessment purposes. According to European directive 2002/44/EC, Effective Action Value (EAV) for WBV is 0.5 m/s^2, whereas Effective Limit Value (ELV) is 1.15 m/s^2. The result obtained for WBV exposure when driven under stipulated conditions is tabulated in Table 3. It is clear from the table that for all combination of three conditions, the exposure value has exceeded the maximum limit value (ELV Value). It can be observed that WBV exposure in the case of mono shock and dual shock in both rough and smooth condition is higher than the ELV value. Further, the presence of pillion rider has reduced the vibration exposure on the main rider.

The same trend can be observed in smooth road condition. However, addition of pillion rider didn't reduce the exposure level below the specified lower limit (EAV). Thus, WBV exposures possess a serious threat to both main rider and pillion rider. This result agrees with earlier studies which discussed about effect of load on vibration exposure.

Table 3 Variation of WBV with different parameters

Suspension	Pillion rider	Jerk in road condition	RMS acceleration (m/s^2)			Total magnitude of vibration (m/s^2)
			x axis	y axis	z axis	
Mono shock	No	Yes	1.39	1.72	2.33	3.87
		No	0.94	1.15	1.70	2.68
	Yes	Yes	0.78	0.83	1.22	2.00
		No	0.56	0.78	1.24	1.83
Dual shock	No	Yes	1.56	2.01	2.87	4.57
		No	0.90	1.17	2.47	3.22
	Yes	Yes	0.93	1.32	2.07	3.06
		No	0.71	0.80	1.52	2.13

Table 4 Variation of HAV with different parameters

Suspension	Pillion rider	Jerk in road condition	RMS acceleration (m/s^2)			Total magnitude of vibration (m/s^2)
			x axis	y axis	z axis	
Mono shock	No	Yes	1.12	1.25	1.40	2.1
		No	0.72	0.84	0.89	1.42
	Yes	Yes	1.11	1.20	1.28	2.07
		No	0.70	0.82	0.87	1.4
Dual shock	No	Yes	1.12	1.26	1.49	2.25
		No	0.62	0.87	0.98	1.45
	Yes	Yes	1.11	1.25	1.47	2.22
		No	0.61	0.85	0.95	1.43

3.4 *Variation of HAV with Different Parameters*

For HAV exposure, ISO 5349 standard was used for measurement as well as assessment purposes. According to European directive 2002/44/EC, effective action value for WBV is 2.5 m/s^2 whereas effective limit value is 5 m/s^2. The result obtained for HAV exposure when driven under stipulated conditions is tabulated in Table 4. It is clear from the table that for all combination of three conditions, the exposure value is within the maximum limit value (ELV Value). It can be observed that HAV exposure in the case of mono shock and dual shock in both rough and smooth condition are lower than the EAV value. It can be observed that presence of pillion rider has reduced the vibration exposure on the main rider. Thus, load or pillion rider presence in the vehicle can reduce the HAV exposure to a considerably lower value compared to EAV value mentioned by the European directive.

Similarly, addition of pillion rider when driving through smooth road condition has reduced the HAV exposure value to a negligibly lower value. Hence, HAV does not have serious influence over the pain and discomfort felt by riders.

3.5 *Variation of 8 h Reference Value Among 3 Axes*

The total experiment was conducted only for 15 min duration due to time constraints. So, these vibration values should be assessed on an 8-h reference period. By doing this, vibration exposure levels on each axis during daily working hour can be calculated for mono shock as well as dual shock motorbikes. These values can be analyzed with the standard values set by European directive for assessing the risk associated with the job. Figure 3 represents the variation of 8-h reference value for whole body vibration value along three axes. Also based on these values, Total Magnitude of Vibration (TMV) was also determined. It can be observed from that 8-h reference value for x-axis is within the standard EAV level. But for y- and z-axis, they have

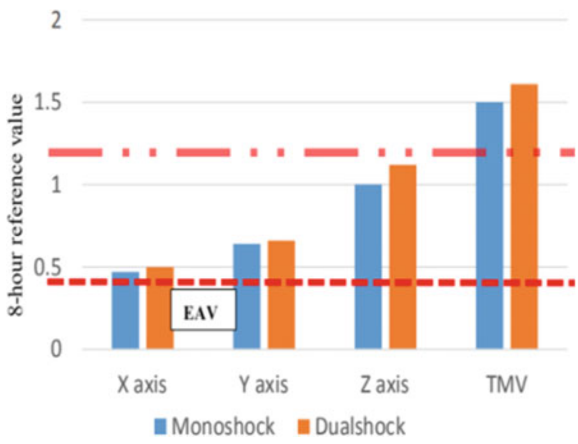

Fig. 3 Variation of 8-h reference WBV value among three axes

exceeded the EAV level. However, these values are within the ELV level. Hence, some sort of technical or organizational ergonomic intervention should be developed for reducing the WBV exposure level.

Similarly, Fig. 4 represents the 8-h reference value for hand arm vibration for three axes. Like former case, total magnitude of vibration based on 8-h reference value was also determined. It's clear from the figure that the 8-h reference values for all three axes were lower than the EAV value specified by the standards and directives. Based on the values for three axes, total magnitude of vibration was also calculated. This value was also lower than the EAV value and ELV value specified. Hence, the problem of HAV is not so severe in the case of two-wheeler riders. If left untreated, this can cause serious ergonomic injuries. Quantification of HAV can help to determine the duration in years required to produce symptoms of HAVS in these riders.

For mono shock, the number of years of exposure (D_y) was found to be 27 years whereas for dual shock it was 25 years (10% probability) by using (1). If this vibration

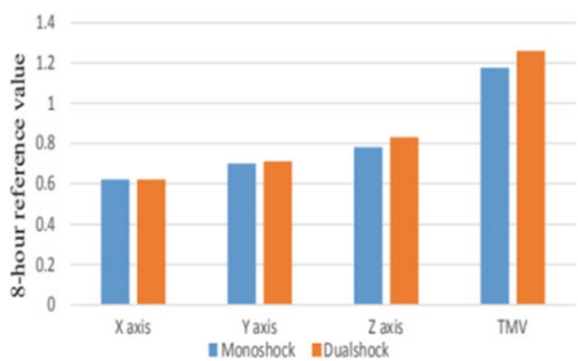

Fig. 4 Variation of 8-h reference HAV value among three axes

exposure continues for prolonged period, these exposures can produce symptoms of HAVS. If left untreated, this can cause serious ergonomic injuries.

4 Discussion

The preliminary study was carried out for qualitative assessment of the risk due to vibration exposure among two-wheeler riders. Modified Nordic questionnaire was used and odd ratio test was also calculated to assess the magnitude of risk of vibration exposure on producing MSDs in two-wheeler riders. The study also found that vertebral regions (upper and lower back along with neck) and distal upper extremities (elbow, wrists) are mostly affected by vibration exposures. The result is found to be consistent with the findings of other authors (Anoop and Binoosh 2019; Azmir et al. 2015; Singh 2019).

For the quantitative assessment of HAV and WBV exposures on these riders, the factors such as pillion rider, road condition and suspension type were considered. The magnitude of vibration exposure in the case of both WBV and HAV was found to be increasing as road condition changes from smooth road to rough road. This can be attributes to irregularities in the road surface such as humps, pot holes, etc. This result was found to be consistent with the findings of (Kharat and Dhande 2015) who concluded that magnitude of vibration exposure (HAV and WBV) increases as road condition varies from smooth to rough condition. Presence of pillion riders has reduced the vibration exposure on the main rider in the case of both HAV and WBV and consistent with the findings (Malchaire et al. 1996; Singh 2019) load on the vehicle have influence over the vibration exposure on the operator. The result also was found to be consistent with the findings (Cochran 1977) who have concluded that pillion rider presence can reduce the exposure level on main operator. According to his studies, pillion rider feels more discomfort due to vibration exposure caused by speed bumps, pot holes, etc. During qualitative assessment, majority of participants responded that mono shock bikes are more comfortable than dual shock bikes. This was found to be consistent with the results of qualitative assessment. The vibration exposure values in the case of both HAV and WBV for mono shock vehicle were found to be lower than the values of dual shock vehicles.

Qualitative assessment results have shown that riders have more chance for occurrence of DMSDs due to vibration exposure in body parts such as wrists, elbows, upper and lower back. Majority of the respondents have reported pain in these regions during the survey. From qualitative assessment, it was found that WBV exposure is severe compared to HAV. Thus, pain and trouble felt in upper and lower back can be attributed to WBV exposure. However, HAV exposure does not have any influence over the discomfort felt by these riders. The values were found to be lower than the EAV value provided by European directive. Hence, this can be attributed to other ergonomic health hazards like repetitive strain injuries and improper posture.

5 Conclusion

The objective of the study was to quantify WBV and HAV exposure among two-wheeler riders. The study was conducted as per ISO standard and European directive guidelines. Results have shown that WBV exposure is severe in the case of both mono shock and dual shock vehicles. HAV exposure was found to be lower than the specified values provided by European directive 2002/44/EC. The result has shown that the presence of pillion rider has reduced the exposure level on the main rider in the case of HAV and WBV exposure. Results indicated that rough road condition increases the magnitude of WBV and HAV exposure.

WBV exposure was found to be serious for the two-wheeler riders and this can be the causal factor for pain and discomfort felt by riders in lower and upper back. The pain and trouble in hands of these riders can be attributed to other hazards such as repetitive strain injuries and improper posture. Future studies can be conducted using advanced devices to assess the effect of resonance on body parts due to vibration exposure. Factors such as effect of seat condition on vibration exposure, exposure on pillion riders can also be incorporated in future studies.

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Chapter 43
Working Posture Analysis of Female Residential Building Sweepers Using OWAS Method

Hemani Malhotra and Manjit K. Chauhan

1 Introduction

The sweepers come from disadvantaged communities of society where they feel significant social exclusion and internally adopt belief of inferiority (Patwary 2010). Musculoskeletal injuries are a major occupational concern worldwide. Awkward working posture is a physical factor identified in occupational musculoskeletal injuries (Lee and Han 2013). The National Institute for Occupational Safety and Health reported that awkward working posture had a strong relation to the causation of musculoskeletal injuries.

Sarkar et al. (2016) revealed that manual material handling activities involve awkward postures which leads to occupational health problems. Many studies have found that sweepers are prone to develop musculoskeletal problems in the back, neck, shoulders, arms and hands (Wang and Chiou 2016).

One of the most important factors which leads to work related musculoskeletal problems is the poor posture adopted during work (Burdorf et al. 1991), ranging from minor back problems to severe handicapping (Keyserling 1986; Aaras et al. 1988).

One method for analyzing and controlling poor working postures in industry is the Ovako Working Posture Analysis System (OWAS) (Karhu et al. 1977). OWAS is a working postures analysis method based on observation to identify the poor working postures which cause musculoskeletal disorders. OWAS method, designed to help the work analysts, is a work sampling method based on the analysis of working postures examples collected in certain time periods (Akay et al. 2003).

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Sweepers are susceptible and suffer from various job-related health problems due to limited education and lack of knowledge on occupational health hazards. This activity is performed manually involving a variety of awkward postures without taking much precautionary measures which leads to various postural problems among sweepers. The purpose of this study was to investigate the postures adopted during the sweeping of residential buildings and to determine the prevalence of musculoskeletal pains among residential building sweepers of urban Mumbai city.

2 Methodology

Study Design

A cross-sectional study was carried out on 200 female sweepers working in western suburban residential buildings of Urban Mumbai City.

Participants

The study was conducted on female sweepers in western suburban area residential buildings of Mumbai City. The age of the subjects was between 18 and 60 years of age. Sweepers with at least five years of experience in sweeping job were included in the study. Many residential societies from the suburban Mumbai area were approached. The permission to conduct study was taken from building secretaries. The consent of the sweepers was taken prior to the commencement of the study.

Sample Size

A total of 200 sweepers were selected for musculoskeletal study and postural study was carried out on 120 sweepers. Convenient sampling method was adopted as only those societies who gave permission were considered.

Data Collection

Questionnaire was used to collect the necessary information followed by interview technique to elicit information on sweepers. The musculoskeletal problems experienced by the sweepers were assessed through a validated tool, i.e. Nordic Questionnaire Technique designed by Kuorinka et al. (1987). The postures that were adapted by the sweepers while sweeping were assessed through the method of observation, photographs and standardized evaluation method, i.e. OWAS method developed by Karhu et al. (1977). The OWAS action categories are given below.

OWAS action category	OWAS codes
No corrective measures required	1
Corrective measures required in near future	2

(continued)

(continued)

OWAS action category	OWAS codes
Corrective measures required as soon as possible	3
Corrective measures required immediately	4

3 Results

A cross-sectional study was conducted on 200 female sweepers working in residential buildings in Mumbai city to identify and assess the postural problems and the incidence of musculoskeletal problems experienced by the residential building sweepers.

Demographic Information

The demographic characteristics of the respondents are presented in Table 1. The data on age, educational background and marital status were collected.

The minimum age of sweepers in the study was 21 years, whereas the maximum age of 60 years. The mean age of all subjects was 38.4 ± 10.3 years. Table 1 gives the age distribution of sweepers in the study. Majority (34%) of sweepers in the study were from the age group of 31–40 years, followed by 27.5% sweepers being the age

Table 1 Demographic profile of the female residential sweepers

Parameters	Sweepers (n = 200) frequency	Percentage (%)
Age (Years)		
21–30 years	55	27.5
31–40 years	68	34.0
41–50 years	43	21.5
51–60 years	34	17.0
Educational level		
Illiterate	44	22.0
Primary School Education	138	69.0
SSC	16	8.0
HSC	2	1.0
Marital status		
Married	170	85.0
Unmarried	16	8.0
Widow	10	5.0
Divorcee	4	2.0

group of 21–30 years. Around 21.5% sweepers were in the age group of 41–50 years and the rest 17% were in the age group of 51–60 years.

With regards to the educational qualification and marital status of the residential building sweeper, the highest percentage (69%) of sweepers had only completed primary schooling, whereas 22% were illiterate. Only 8% sweepers had completed SSC, whereas 1% had completed HSC. Most sweepers were married (85%), whereas the rest 15% were either unmarried, widow or divorced.

Activities Performed by the sweepers

The sweeping activity involves various activities that needs to be followed by residential building sweepers which was analyzed and divided into 6 elementary jobs and is presented in Table 2.

Posture adopted by the respondents while performing the activity

Field observations show that because of continuous sweeping with traditional brooms and carrying collected waste either in the wheelbarrows/large bins to the community dustbins manually adopting habitual posture puts undue stress on workers resulting in MSD's. Therefore, the working postures of the respondents while performing different activities while sweeping residential buildings were observed and analyzed using OWAS method. The position of back, upper limbs, i.e. arms and lower limbs, i.e. legs as well as load of force used for lifting and carrying activities were considered for analysis of posture which is presented in Fig. 1.

Figure 1 shows the analysis of working posture adopted during residential building sweeping using OWAS Technique by female sweepers. The results of the OWAS identified that posture adopted during putting garbage into the bin fell into action

Table 2 Activities and postures adopted by the residential building sweepers

Sr. No	Activities performed	Posture adopted
1	Collecting garbage and putting it into big bin	Bending forward to collect dustbin from floor, both arms below shoulder level and weight of the body on one leg, adopting forward bending with arms abducted while putting garbage into a big bin and then again keeping the dustbin in place
2	Sweeping passage area	Bending forward with both the arms below shoulder level and sometimes body weight on one leg with slight bent at knee
3	Sweeping staircase	Forward back bent and twisted, with arms abducted
4	Sweeping parking area	Bending forward with both the arms below shoulder level, while collecting garbage; standing on both feet with knees bent
5	Pulling garbage bin	Forward bending with both the arms below shoulder level in backward direction, holding the big garbage bin and pulling it in forward direction with the force applied for pulling and with continuous walking
6	Carrying garbage on shoulder	Standing back straight, both the arms above shoulder level and standing on one leg with knee bent

OWAS Score: 2 Activity: Collecting Garbage and putting it into big bin	OWAS Score: 3 Activity: Sweeping Passage Area	OWAS Score: 2 Activity: Sweeping Staircase
		
OWAS Score: 3 **Activity: Sweeping Parking Area**	**OWAS Score: 3** **Activity:Pulling Garbage bin**	**OWAS Score: 4** **Activity: Carrying Garbage on shoulder**
		

Fig. 1 Analysis of working posture adopted during residential building sweepers using OWAS technique

category 4, which was the major poor posture adopted and needed corrective action immediately. The other activity of sweeping passage area, sweeping parking area and pulling garbage bin fell in category 3 that needed corrective action as soon as possible; followed by collecting garbage and putting in big bins and sweeping staircase which fell in category 2 and needed corrective measures in the near future respectively.

Musculoskeletal Problems among sweepers

The musculoskeletal problems experienced by the sweepers were assessed using Nordic Questionnaire Technique. Table 3 describes the occurrence of pain among the residential sweepers.

It is evident from Table 3 that the most commonly affected site was lower back with 85.5% sweepers suffering from lower back pain followed by 83% suffering from shoulder pain. Calf (52%) and upper back (44%) was also a common site of pain in sweepers.

Table 3 Responses on MSD problems experienced by residential building sweepers

Body Parts	Occurrence of pain	Mild pain	Moderate pain	Severe pain	Very severe pain
Eye	–	–	–	–	–
Neck	21.5	8	9.5	4	–
Shoulder	**83**	**20.5**	**48**	**12.5**	2
Upper back	34	12	17	5	–
Elbow	10.5	3.5	6.5	0.5	–
Lower back	**85.5**	**13**	**54**	**18**	0.5
Arm	28	9	11	7	1
Wrist	19.5	7	8.5	3	1
Thigh	2	0.5	1	0.5	–
Knee	23	4.5	11.5	5	2
Calf	**52**	**8**	**26.5**	**14.5**	3
Feet	17.5	3	8.5	5.5	0.5

*The figures indicate percentage

4 Discussion

The current study focused on the posture and MSD problems of female residential building sweepers. The workers adopt back bent, awkward and harmful posture leading to musculoskeletal problems as revealed by OWAS postural analysis method. Some of the activities identified as unsafe postures were putting the garbage in the bin, sweeping passage areas, sweeping parking areas and pulling garbage bins that needed urgent attention and corrective measures to prevent further deterioration. Similar Ph.D. study conducted by Chauhan (1997) on railway platform sweepers found workers performing similar activities like sweeping platforms, sweeping stairs, collecting garbage, putting it in a basket and dumping it in a big bin. The study recommended that correct posture at work should be ensured to reduce postural stress and fatigue as postural stress was recognized as one of the causative factors for high physiological cost and fatigue.

In the present study the daily occurrence of pain among female sweepers was very high and majority of them suffered from lower back and shoulder pain; followed by pain in the calf and upper back. The physical efforts required to carry out various activities of sweeping like lifting, carrying, pushing and pulling are very high that results in MSD's. Other reasons which are attributed towards the pain are marriage. Child bearing and household work. Chauhan (1997) also found low back and shoulder pain as a major musculoskeletal problem reported by railway platform sweepers. Another preliminary study by the present author (Malhotra 2017) on women residential building sweepers showed that the majority of the female sweepers complained of entire body pain along with pain in arm, shoulder, hand/wrist and low back, respectively. A study by Das et al. (2013) on the women sweepers working under the Midnapore Municipality reported that female sweepers experienced back pain

(82.69%). Study by Suthar and Kaushik (2013) on farm women found a high incidence of pain reported by farm women in various body parts, viz. neck, shoulder, elbow, wrist, mid back and low back, knee and calf muscles in overburdened rural women indicates that women are at continuous health risk. Bijetri and Sen (2014) found that women working in the manual brick manufacturing industry had 90% of body pain in wrists, back, knees, thighs, ankles due to awkward posture adopted by them and results of OWAS showed the corrective measures to be taken immediately. Chung et al. (2005) found that workers in the manufacturing industry in Korea were exposed to repetitive manual tasks adopting prolonged poor working postures that were closely related to back pain and other symptoms of musculoskeletal disorders. Results showed a linear relationship between the two types of discomfort, with the shoulder and low back postures being the dominant factor in determining the whole-body postural stresses.

5 Conclusion

The study concludes that the poor and prolonged static postures adopted by the female sweepers during the activity of sweeping needed corrective action immediately and for some postures immediate solution is needed as soon as possible. Poor postures adopted by them led to a number of musculoskeletal problems. Sweeping occupation includes various postures to be adopted which are repetitive and the awkward postures leads in the development of musculoskeletal problems. In addition, the sweepers are ignorant about the postures to be adopted while performing the sweeping activity. It was therefore evident that a major ergonomic guideline on right posture, safe measures, periodic medical check-up of the workers and ergonomic designing of brooms is essential. An intervention study is needed by conducting training programmes to improve the sequence of work activities, work posture adopted, design ergonomically designed tools like carts, brooms, etc., and improve the working conditions to minimize the occupational problems.

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Chapter 44
Workplace Heat Stress and Its Effect on Worker's Health Employed in Glass Manufacturing Unit

Sonia Tewari and Deepa Vinay

1 Introduction

Heat stress is one of the major burdens to human beings in the current scenario. People working in numerous industries are exposed to excessive heat burdens in addition to the environment due to which workers confront many health-related problems. Industries having an extremely hot environment are "iron, steel, glass, and ceramic units, rubber, foundries, coke ovens, mines, and construction industries" (Sabnavis et al. 2018). Heat stress can be at outdoor places or indoor workplaces. The sources of heat stress in indoor workplaces are "furnaces, ovens, smelters and boilers" (Chen et al. 2003) and workers working nearby these sources were at a higher risk to heat stress especially during summers (Xiang et al. 2014). A study on steel plants reports that in winters, the temperature near the furnaces has ranged from 35.5 to 46.5 °C when the outdoor temperature was only 14–18 °C (Chen et al. 2003).

The glass industry is also among one of the most vulnerable industries besides having an informal arrangement. A glass manufacturing unit uses 95% of the cullet (waste glass) and 5% of the batch (a mixture of sand, sodium and chemicals) as its basic raw material. A mixture of this material is fed to the furnace and the quantity of raw material is based on consignment. Coal is used for generating heat in the furnace. The mixture is melted to near about 1500 °C. This melting process amplified the heat levels and exposure of radiant heat to workers (Brahmapurkar et al. 2013). The working conditions inside glass manufacturing units are far beyond the normal range of heat and temperature. The glass industry workers are exposed to various occupational health hazards due to high temperature and heat conditions (NIOSH 1992). In an extremely hot environment, workers work under heat stress setting, resulting in deterioration of their efficiency and productivity at work (Pourmahabadian et al. 2008). It also impairs their health and sometimes even leads to life

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threatening conditions (Sabnavis et al. 2018). The symptoms of heat-related illness in the workplace are headache, nausea, vomiting to severe form of heatstroke, which if untreated can leads to death (Parameswarappa and Narayana 2014). Apart from the general hazards such as heat and noise exposure, respiratory and physical hazards, there are psychosocial and physical environment impacts of such manufacturing units on the workers (Wintour 2015). The dehydration induced as a result of heat stress leads to exceeding the human body capacity to cope, resulting in a decline of the mental functions and other performance-related issues in the glass industry workers (Gopinathan et al. 1988). Heat stress is among one such factor which has a very severe negative impact on worker's mental and psychological health along with the physical health hazards.

Also, the Glass manufacturing sector has witnessed tremendous changes in terms of growth and expansion (Wintour 2015). At present, the market size of the glass industry in India has been estimated at around Rs. 225 billion (Sabnavis et al. 2018). As per the CARE report, the industry earns a direct livelihood for approximately 30 lakh people and nearly 7 lakh people get indirect employment through glass manufacturing units.

Keeping in mind the severity of the heat stress conditions and engagement of workers in these informal sectors, it is important to assess the heat hazards among workers and suggest some preventive measures so that the negative impact on worker's health can be minimized and wellbeing can be enhanced.

2 Material and Methods

Selection of respondents: The manufacturing of glassware or items includes four types of tasks that are performed stepwise at a time:

(1) ball making (the molten glass was drawn from the furnace forming a ball-like structure with the help of blowing pipe),
(2) ball blowing (the molten glass ball is then blown with mouth to cool the glass),
(3) mold handling (the molten ball was again blown by the blowers accordingly based on the molds which were handled by mold handlers) and
(4) Helping task (The final product was then taken to the inspection unit by the helpers).

For one consignment, these workers worked in a team of 8–10 members for four types of an assigned task continuously for half an hour provided with half an hour rest. When the first team rests another team takes their place and works for another half an hour. And at a time, there were 5–8 consignments running simultaneously. The workers work for 6 h. The manufacturing unit works for 24 h*7 in 4 shifts (Table 1) of 6 h. A total of 120 workers from the manufacturing unit performing the mentioned tasks were selected conveniently without replacement for assessing their heat stress. The 30 glass blowers were selected for the heat hazard assessment as these groups of people were more prone to heat stress.

Table 1 Working shift in glass manufacturing unit

Shift number	Timings
1	8:00 a.m. to 2:30 p.m.
2	2:30 p.m. to 8:30 p.m.
3	8:30 p.m. to 2:30 a.m.
4	2:00 a.m. to 8:30 a.m.

3 Tools and Methods

A 24-h analysis of the various heat stress parameters was done using a heat stress monitor QUESTemp° 36 in November 2018. As this manufacturing unit runs around the clock and the workers work in 4 shifts (Table 1).

Heat Stress Monitor was placed 9 feet from the furnace, 5 feet from the distributor and 3 feet from the bay. The readings were recorded at an interval of 10 min.

A checklist of the subjective symptoms was used to assess the heat stress of the workers. Heat hazard assessment of the glass blowers was done using the OSHA method.

Heat hazard assessment was done using the OSHA method and it helps in deciding whether the heat related hazard present in a workplace either indoor or outdoor. The steps for the assessment of heat are

Step 1: Determine the WBGT-In using the heat stress monitor.

Step 2: Determine the WBGT effective by adding a clothing adjustment factor (CAF). The CAF Table was given in Table 2

Step 3: Determine the metabolic work rate.

The ACGIH metabolic work rates define the effect of internal heat production to the core temperature of the body when exertion to the body increases impacts to the body core temperature from the heat produced internally as exertion increases. The work category can be selected from the given Table 3

$$\mathbf{MRest} = \mathbf{work\ expectations}(\mathbf{Watts\ from\ Table}\ 2)$$

Table 2 Clothing adjustment factor (CAF)

Clothing worn	CAF
Clothes wear for working (long sleeves and pants). E.g. Standard cotton shirt and pants	0
Coveralls (w/only underwear underneath). Examples: Cotton or light polyester material	0
Woven clothing with double-layer	3
SMS polypropylene coveralls	0.5
Micro-porous fabric made up of polyolefin coveralls	1
Limited-use vapor-barrier coveralls. Examples: Encapsulating suits, whole-body chemical protective suites, firefighter turn-out gear	11

Table 3 Work category and metabolic rate

Work category	Metabolic rate (Watts)	Example
Rest	115	Sitting
Light	180	Sitting, standing, light arm/hand work and occasional walking
Moderate	300	Normal walking, moderate lifting
Heavy	415	Heavy material handling, walking at a fast pace
Very heavy	520	Pick and shovel work

Adopted from ACGIH “2017 TLVs and BEIs”

Table 4 TLV limits based on the type of activity and Work and recovery regime

Work and recovery (TLV) (%)	Light	Moderate	Heavy	Very heavy
75–100	31.0	28.0	26.0[a]	23.5[a]
50–75	31.0	29.0	27.5	25.5[a]
25–50	32.0	30.0	29.0	28.0
0–25	32.5	31.5	30.5	30.0

[a] Values not specified by ACGIH have been estimated for continuity
Cited from American Conference of Governmental Industrial Hygienists

$$\times \textbf{ worker body weight}/70 \textbf{ kg or } 154 \textbf{ lbs}$$

Step 4: Determination of Threshold Limit Value (TLV) or Action Limit: The threshold limit was decided using Table 4.

4 Results

In this study, the mean age of the respondents was 32.125 ± 7.67 years and 60% of them belong to Other Backward Class, followed by Scheduled Caste (20.83%) and the rest 19.16% were unreserved. This study revealed that more than three-fourth of the respondents were literate (approximately 84%) and a maximum (33.3%) of them were high school passed in the glass manufacturing unit.

It was clearly evident from Table 5 that the dry bulb temperature was found to be the highest and common in shift 2 and shift 3, i.e. 34.69 ± 0.00 °C. The globe temperature was highest in shift 2 (52.50 ± 1.94 °C). The Wet Bulb Temperature was recorded highest in the first shift (25.62 ± 0.61 °C). The humidity recorded by the instrument in the manufacturing unit was found to be highest (11.15%) in shift4. And the determining factor of heat stress was Wet Bulb Globe Temperature Indoor (WBGT-In) and this was found to be 33.02 ± 0.92 °C in shift 1, 33.78 ± 1.08 °C in shift 2, 31.30 ± 0.83 °C in shift 3 and 31.88 ± 1.44 °C in shift 4 (Fig. 1).

Table 5 Heat stress parameters prevailing in the glass manufacturing unit according to worker's working shift

Shift no		Dry bulb temperature (°C)	Globe bulb temperature (°C)	Wet bulb temperature (°C)	Humidity (%)	WBGT In (°C)
Shift 1 (8:30 a.m. to 2:30 p.m.)	Avg	31.02	50.29	25.62	10.75	33.02
	SD	1.88	1.89	0.61	2.65	0.92
	Max	34.56	53.63	26.84	24.00	34.79
	Min	24.98	43.31	23.61	6.00	29.72
Shift 2 (2:30 to 8:30 p.m.)	Avg	34.69	52.50	25.76	7.33	33.78
	SD	0.00	1.94	0.70	1.34	1.03
	Max	34.69	55.08	27.42	10.00	35.41
	Min	34.69	49.59	24.18	5.00	31.87
Shift 3 (8:30 p.m. to 2:30 a.m.)	Avg	34.69	47.72	24.26	11.03	31.30
	SD	0.00	1.70	0.56	1.37	0.83
	Max	34.69	51.53	25.56	14.00	33.16
	Min	34.69	44.11	23.09	8.00	29.40
Shift 4 (2:30 a.m. to 8:30 a.m.)	Avg	33.12	48.77	24.65	11.15	31.88
	SD	4.03	2.07	1.21	1.41	1.44
	Max	37.62	52.65	27.62	15.00	35.05
	Min	24.09	45.69	23.00	8.00	29.97
Overall	Avg	33.104	49.42	24.95	10.38	32.29
	SD	2.34	2.53	1.02	2.25	1.42
	Max	37.62	55.08	27.62	24.00	35.41
	Min	24.09	43.31	23.00	5.00	29.40

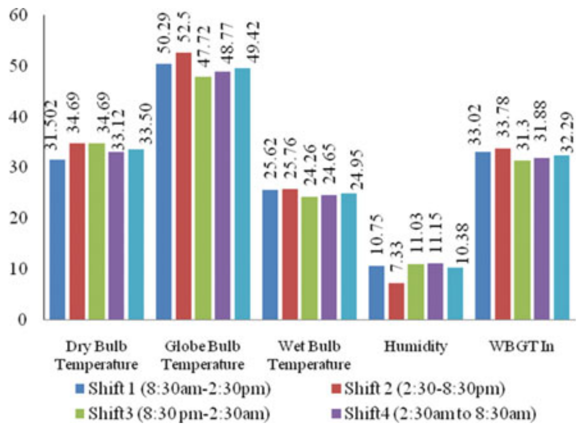

Fig. 1 Shift wise assessment of heat stress parameters

The net value for the dry bulb temperature was 33.104 ± 2.34 °C, for globe bulb temperature was 49.42 ± 2.53 °C, for wet-bulb temperature was 24.95 ± 1.02 °C. The Net value for humidity was 10.38 ± 2.25% and the mean value of WBGT-In was found to be and 32.29 ± 1.42 °C. So, we can conclude that the workers were more exposed to radiant energy. As radiant energy and ambient temperature were high (30.38 °C), so the humidity of that area was very low (10.38%).

Table 6 represents the various parameters for assessing the heat hazard of the workers and it was found that the workers were exposed to excessive heat stress while working because the WBGT value exceeds the recommended threshold limit values (29 °C) (ACGIH 2004). The WBGT was 32.29 °C and the clothing adjustment factor was zero as workers were wearing a cotton shirt and pants. The average metabolic rate of the workers was found to be 264.29 W ranging from 184.29 to 390 W. It was very clear from Fig. 2 that all the workers were working under excessive heat

Table 6 Heat hazard assessment of the workers

Heat hazard assessment	
WBGT	32.29 °C
WBGTeff = WBGT-In + Clothing Adjustment Factor (CAF) (Use Celsius)	32.29 (clothing adjustment factor is zero)
Height (in cms)	166.97 ± 7.36
Weight (kg)	36.63 ± 7.38
Minimum metabolic work rate	184.29 W
Maximum metabolic work rate	390.00 W
The metabolic work rate	264.29 ± 47.54 W (moderate work category)
Determine if exposure was above the TLV	29.0 °C

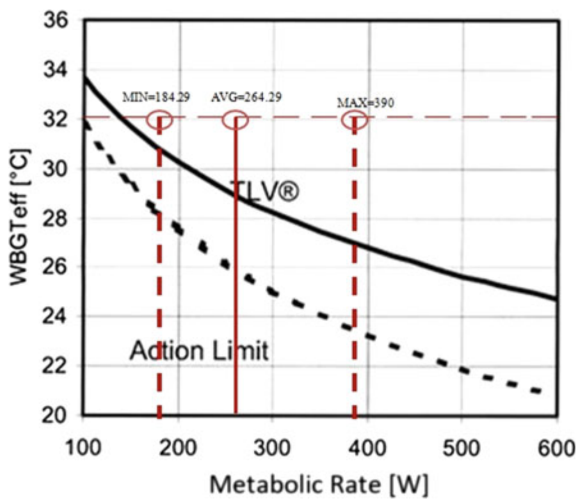

Fig. 2 ACGIH TLV and action limit for workers based on metabolic rate and WBGTeff

exposure as from minimum to maximum range of metabolic rate comes above the action limit as well as TLV.

Exposure to heat in a workplace may cause many health problems starting from heavy sweating and skin rash to fatal heat stroke. Table 7 reflects the subjective symptoms of heat stress reported by the workers performing the various task in the manufacturing unit. It is inferred from Table 6 that the majority of the workers performing different tasks complained about the common symptoms. These symptoms were the

Table 7 Subjective symptoms of the heat stress reported by the workers

						N = 120
S no	Symptoms of heat stress[a]	Ball maker n1 = 34	Ball blower n2 = 37	Mold handlers n3 = 26	Helper n4 = 23	Total (N = 120)
1.	Painful muscle spasms, usually in the legs or abdomen	9 (26.47)	15 (40.54)	22 (84.61)	12 (52.17)	58 (48.33)
2.	Brief Fainting	10 (29.41)	10 (27.02)	–	–	20 (16.67)
3.	Blurred Vision	13 (38.23)	20 (54.05)	15 (57.69)	3 (13.04)	51 (42.50)
4.	Dehydration	25 (73.52)	22 (59.45)	11 (42.30)	11 (47.82)	69 (57.50)
5.	Reduced movement	7 (20.58)	17 (45.94)	1 (3.84)	5 (21.73)	30 (25.00)
6.	Red bumpy rash with itching	8 (23.52)	14 (37.83)	8 (30.76)	16 (69.56)	46 (38.33)
7.	Pale and clammy skin	6 (17.66)	8 (21.62)	5 (19.23)	5 (21.73)	24 (20.00)
8.	Possible fainting	14 (41.17)	16 (43.24)	5 (19.23)	3 (13.04)	38 (31.67)
9.	Weakness and fatigue	21 (61.76)	31 (83.78)	26 (100)	19 (82.60)	97 (80.83)
10.	Headache	23 (67.64)	20 (54.05)	17 (65.38)	14 (60.86)	74 (61.67)
11.	Nausea	13 (38.23)	12 (32.43)	5 (19.23)	3 (13.04)	33 (27.50)
12.	Dizziness	3 (8.82)	1 (2.70)	3 (11.53)	-	7 (5.83)
13.	Heavy sweating	32 (94.11)	35 (94.59)	26 (100.00)	20 (86.95)	113 (94.16)
14.	Body temp slightly elevated	34 (100.00)	36 (97.29)	24 (92.30)	22 (95.65)	116 (96.66)
15.	Cessation of sweating	2 (5.88)	2 (5.40)	–	–	4 (3.33)
16.	Skin hot and dry Red face	27 (79.41)	35 (94.59)	24 (92.30)	19 (82.60)	105 (87.50)
17.	Unconsciousness	6 (17.64)	4 (10.81)	–	–	10 (8.33)
18.	Confusion or erratic behaviour	7 (20.58)	11 (29.72)	11 (42.30)	2 (8.69)	31 (25.83)

Note [a]Multiple responses
Values in the parenthesis represent percentage

rise in their body temperature (96.66%), heavy sweating (94.16%), skin hot and dry red face (87.50%) and weakness and fatigue (80.83%). Although other symptoms like headache (61.67%), dehydration (57.50%), painful muscle spasms (48.33%), blurred vision (42.50%), possible fainting (31.67%), nausea (27.50%), confused or erratic behavior (25.83%) and reduced movement (25%) were also reported by the workers. While very few workers reported brief fainting (16.67%), unconsciousness (8.33%), dizziness (5.83%) and cessation of sweating (3.33%).

The symptom of the cessation of sweating is the distinguishing feature of heat stroke along with unconsciousness and a rise in body temperature. So, it can be said that 3.33% were suffering from heat stroke and it was an alarming situation. The heat stroke was reported by workers performing ball making task and ball blowing task and this group of workers is more prone to such symptoms as they are the one who works in close contact with the furnace. Nausea is the characteristic feature of heat exhaustion along with heavy sweating, headache, dizziness. It can be concluded that 27.50% of the workers were suffering from heat exhaustion. Heavy sweating was the result of heat stress, heat exhaustion, heat cramps. Hence 96.66% were under heat stress conditions.

5 Discussion

The present study investigates the effect of heat stress on the workers of the glass manufacturing unit. The mean age and literacy level of the workers were found to coincide with building construction industry workers and were also found to be 32 years and 79% were literate (Tiwary et al. 2012). The majority of the construction laborers of Varanasi City were from the local community of SC and OBC (Raj and Singh 2018) which was also found similar to the study.

The heat-related symptoms reported in the study by the glass manufacturing workers also reported the alike symptoms of "heat exhaustion (28.1%), heat cramps (22.0%), heat hyperpyrexia (2.6%) which indicates the significant occurrence of heat stress among glass factory workers and burn was reported to be a direct effect of heat exposure among 27.7% of the workers of Central India" (Brahmapurkar et al. 2013). Fire-fighters also reported similar symptoms like heat exhaustion (18.3%), heat cramps (6.1%) and heat pyrexia (4.2%) (Patel et al. 2006).

A report on "vulnerability to heat stress: scenario in Western India" reported that workers in the iron industry (5.9%) and in the ceramic industry (20.3%) experienced heat cramps (Nag and Nag 2009).

The heat stress-related discomforts symptoms reported by ceramic and iron foundry workers were heavy sweating, elevated body temperature, sleeplessness, excessive thirst, muscular discomforts and fatigue (Majumder et al. 2016). They also reported that skin-related disorders like a red face, dry skin, bumps, itching were significantly higher among iron foundry workers, whereas sleeplessness, high blood pressure, heavy sweating, kidney stone, decreased urination, muscular discomforts and fatigue was significantly more among ceramic workers (Majumder et al. 2016).

The present study revealed that the WBGT-In also exceeds the Threshold limit value of 29 °C recommended by ACGIH. Similar findings were obtained which shows that WBGT was 40 °C against the ACGIH TLVs of 26.7 °C in front of an IS machine. The WBGT exceeds the TLV limits in all the areas of the manufacturing section WBGT in the glass manufacturing industry. They also suggested that the WBGT observation requires quick action to control heat stress-related problems in the manufacturing area of glass manufacturing units (Srivastava et al. 2000).

Another study also revealed similar findings in which high WBGT against TLV was found in raw material, furnace, the manufacturing and lehr section, whereas WBGT in sorting and packing section was within the permissible limit. They also concluded that the major contributing factor to the heat stress was radiant heat as the globe temperature was found to be higher than dry bulb temperature at raw material, furnace, manufacturing and lehr section (Brahmapurkar et al. 2012).

6 Limitation

The present study was limited to the manufacturing unit and was conducted in the winter season only due to procedural delay in obtaining informed consent from the higher authority of the industry.

7 Conclusion

The mean value of WBGT-In was found to be 32.29 + 1.42 °C shows that the workers were highly exposed to radiant energy as WBGT-In exceed TLV and also all the blowers were working above the TLV value of 29 °C. The symptoms of heat stress were reported by all the workers. As the study was conducted in the winter season, the further inference can be drawn that the heat stress during summers and in the rainy season has a greater impact on the workers' health.

There is a limited research study on analyzing heat hazards by using OSHA's heat hazard assessment method, therefore, this study also recommends that the worker's exposure to heat stress in various heat stress conditions should also be assessed using this method.

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Retraction Note to: A Survey on Early Prediction of Autism Spectrum Disorder Using Supervised Machine Learning Methods

K. N. Praveena and R. Mahalakshmi

Retraction Note to:
Chapter 2 in: N. K. Rana et al. (eds.), *Technology Enabled Ergonomic Design*, Design Science and Innovation, https://doi.org/10.1007/978-981-16-6982-8_2

The Editors have retracted this chapter. After publication, concerns were raised because of the unusual phrases used in the article (arbitrary timberland, counterfeit neural organisation). The authors did not provide a reasonable explanation. Post publication peer review confirmed that the article is not suitable for publication. The Editors therefore no longer have confidence in the integrity of the data in this article. K.N. Praveena has stated on behalf of all the authors that the authors disagree to the retraction.

The retracted version of this chapter can be found at https://doi.org/10.1007/978-981-16-6982-8_2

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