Gaur G. Ray
Rauf Iqbal
Anindya K. Ganguli
Vivek Khanzode *Editors*

Ergonomics in Caring for People

Proceedings of the International Conference on Humanizing Work and Work Environment 2015

Springer

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Preface

From the December 7–9, 2015, about 175 academicians, researchers, teachers, students, consultants, and others, gathered in Mumbai, India and focused on caring for people through humanizing work and work environment. They came not only from all parts of India, but also from all over the globe to present about 260 papers in different forums of the HWWE 2015 conference. These participants represented many different disciplines and interests, and this is reflected in the spectrum of the papers included in this volume.

Of these papers, around 80 papers were considered suitable by the panel of independent referees for acceptance in the Peer Review category, that is, papers which the authors considered were worthy of consideration in a peer-reviewed publication. An internal review of these 80 papers by the editors following the Springer guidelines resulted in a final selection of 43 quality papers for this volume. Apart from quality, the brief given to the selectors was diversity, the result being that agriculture, accessibility, industry (particularly the un-organized sector), occupational health, and psychophysiology are just some of the themes covered here.

Though the conference organizers' initial paper submission guidelines specified rigorous formatting requirements, there was a fair amount of divergence which needed editorial effort and correspondence with the authors, especially to match the stringent standards of the publisher. The final product is entitled "Ergonomics in Caring for People—Proceedings of the International Conference on Humanizing Work and Work Environment 2015."

HWWE 2015 was the thirteenth such conference under the aegis of the Indian Society of Ergonomics. As in the case of the first conference, the editors of the present volume hope that it will provide guidance to all concerned in ergonomics application, research, and teaching, and lead to a discussion of needs and strategies for the further growth and development of ergonomics.

Mumbai, India	Gaur G. Ray
Mumbai, India	Rauf Iqbal
Kolkata, India	Anindya K. Ganguli
Mumbai, India	Vivek Khanzode

Acknowledgements

The task of organizing a conference is huge and the successful conduction of the conference remains incomplete without the support of many people involved in making the conference a success.

We would like to convey our thanks and gratitude to Prof. Devang Vipin Khakhar, Director, Indian Institute of Technology Bombay (IITB) and Prof. (Ms.) Karuna Jain, Director, National Institute of Industrial Engineering (NITIE), Mumbai. Without their support it would not have been possible to conduct such a mega International Conference on Humanizing Work and Work Environment 2015 and International Symposium on Community Nutrition and Health: A Social Responsibility.

The conference was jointly hosted by the Indian Institute of Technology Bombay (IITB) and National Institute of Industrial Engineering (NITIE); in collaboration with the Punjab Engineering College (PEC) University of Technology, Chandigarh. A special convey of thanks to Prof. Manoj K. Arora, Director, PEC University of Technology, Chandigarh, and Prof. Praveen Kalra Dean Academics, PEC University of Technology, Chandigarh for their continued support.

We take the opportunity to thank International Ergonomics Association (IEA) for endorsing the conference, with special reference to Dr. Yushi Fujita (President, IEA), Dr. Jose Orlando Gomes (Vice President and Treasurer, IEA), Mr. Andrew Todd (International Development Committee Chair, IEA), Dr. Kazutaka Kogi (President, ICOH), Dr. Eric Min-yang Wang (Awards Standing Committee Chair, IEA), and Dr. Rosemary R. Seva (President, Human Factors and Ergonomics Society of The Philippines).

We also would like to thank the Indian Society of Ergonomics, which is the only professional body representing ergonomics/human factors professionals in India with special reference to Dr. A.K. Ganguli (President, ISE), Dr. D. Majumdar (Vice President, ISE), Dr. Debkumar Chakrabarti, (Vice President, ISE), and all other associated members of ISE for their constant support.

We are highly grateful to Dr. P.K. Nag (Conference Chair) for his constant support and guidance in organizing the conference.

We would like to extend our warm greetings to Nutrition Society of India (NSI), Mumbai with special mention to Dr. Kasturi Sen Ray (President), Dr. Meena Godhia (Secretary), Priyadarshini Muley L. (Convener), and very active organizing committee members of NSI for their support throughout the conference making it a grand success.

We would like mention a special thanks to all the International Advisory Committee members and National Advisory Committee members for providing their expertise in helping with the selection and reviewing of the papers received for the conference. We express our gratitude to the scientific committee Dr. A.K. Ganguli and Dr. Vivek Khanzode (Secretary Scientific committee, HWWE2015), and Dr. Rita Patil (Secretary, CNH) for their expert guidance in paper selection for the conference.

A special mention of thanks to Dr. B. Sesikeran (Former Director, National Institute of Nutrition, Vice President, Nutrition Society of India), Dr. Amaresh Chakrabarti (Professor Centre for Product Design and Manufacturing, IISc, Bangalore), Dr. Rosemary R. Seva (President, Human Factors and Ergonomics Society of The Philippines), Dr. Seyed Ali Hosseini (Professor, University of Social welfare and Rehabilitation Sciences, Tehran, Iran), Dr. Anil Kakodkar (Ex-Director, Bhabha Atomic Research Centre (BARC) and Satish Dhawan Chair of Engineering Eminence) who delivered the keynote sessions, and other invited speakers who moderated and also chaired the specific sessions in each of the conference section. We are thankful to all the Invited speakers who shared their experiences from their respective fields during the conference.

We appreciate the efforts of Mr. Nirav Shah (Godrej Interio) Dr. Reena Valecha (Godrej Interio), Charudatta Jadhav (TATA consultancy services), Dr. Arun Garg (Distinguished Professor, University of Wisconsin. Milwaukee), Dr. Deepak Sharan (RECOUP Neuromusculoskeletal Rehabilitation Centre, Bangalore), Mr. Madan Kulkarni (Managing Director Kalakruti Furnitures Pvt. Ltd., MIDC Gokul Shirgaon, Kolhapur), Dr. Prema Ramchandra (Director, Nutrition Foundation of India), and delegates from Mahindra and Mahindra Limited for conducting very effective workshops in the HWWE2015. Participants have been benefited immensely from each workshop.

The gratitude expressed would be incomplete without the mention of the delegates, who came from different parts of the globe and assembled here to share their experiences.

The organizing committee deserves special thanks who worked tirelessly day in and day out to make sure that all things associated with the conference were perfect and in order. A heartfelt thank to all our working team who really need high appreciation and applause for crafting this conference. Special thanks to Ms. Madavi Sathe, Ms. Anuradha Shekhar, Dr. Rupali Sengupta, Ms. Mitra Savanur, Dr. Pooja Singhania C., Dr. Neha Paharia A., Ms. Shama Chavan, Ms. Bijal Lalan, Mr. Amar, Ms. Lavanya, Ms. Payel, Ms. Shreya, Ms. Arundhati, Ms. Shikha, Ms. Priyanka, Ms. Akanksha, Ms. Jayati, Mr. Ankur, Mr. Quashif, and Mr. Himanshu for their endless support in this conference. Endless thanks to Mr. Sajan Pillai who designed the conference website and Mr. Varun Mevada who efficiently designed all the conference materials including printing and publications. The M. Des student volunteers from Industrial Design Centre (IDC) deserve a huge appreciation for managing the conference and assuring the sessions run as per the time schedule. The Selfless help awarded by IDC and NITIE Faculty and staff during the conference is highly appreciated.

We are extremely grateful to Springer for publishing selected full papers through “Peer review” under a special volume namely “Ergonomics in Caring for People—Proceedings of the International Conference on Humanizing Work and Work Environment 2015.”

Finally, we covey our sincere thanks to all the sponsors, i.e., Glanbia Nutritionals, COSMED, Kelloggs, Mahindra and Mahindra Limited, Pukhya Healthcare, TATA consultancy services, Godrej Interio, Eltek Systems, Qualisys, and Vitamin Angels who have not only generously contributed but also acted as well wishers by providing their suggestions as and when required.

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Contents

About the Editors

Prof. Gaur G. Ray is currently appointed as the Ramkrishna Bajaj Chair Professor of the Industrial Design Centre (IDC) at the Indian Institute of Technology Bombay (IITB). He recently got superannuated and been offered the 'Professor Emeritus Fellowship' Position by IITB from July, 2017. He was also the Head of the Department from 2009 to 2013 and responsible as the Head of the Ergonomics program of the institute. His past roles includes being appointed as Visiting Faculty at the Department of Engineering Design, Tufts University, USA, Department of Human Work Sciences, Lulea University of Technology, Sweden, and several other Universities. He was the founder member and served as the Honorary President of the Indian Society of Ergonomics for about 10 years and also was the Chairperson of the Ergonomics Section (PG 15), Bureau of Indian Standard, for 9 years. Professor Gaur G. Ray has also been involved in a number of international relations development projects including research collaborations between the Industrial Design Centre (IDC) at IITB and the Institute of Ergonomics (IAD) at TU Darmstadt in Germany and other universities. His major activities are in the areas on application of ergonomics in product development, for the people at the bottom of the pyramid, agriculture sector, geriatric population, automotive industry and design for the special people. He has published more than 30 papers in International Journals, Presented more than 130 papers in different national and International conferences, completed more that 15 funded projects by DST, MHRD, AICTE, and other organizations, completed more than 8 major consultation projects starting from vehicle design, workstation design, low cost agricultural tools design, etc. He recently completed the entire driver's cabin design, layout, control panel organisation, and chair design for Mumbai Railway Vikas Limited. He has been awarded "J.N. Maitra" Gold Medal in the year 1998 by the Physiological Society of India for contribution in Indian Ergonomics. He was invited as Keynote Speaker by the International Ergonomics Association in 2015 at Melbourne. He has also received several best paper awards in the International and International conferences. In the year 2014, he received the Ramkrishna Bajaj Chair Professor Fellowship Award from IITB for 3 years. Professor Ray has guided seven PhDs, more than 20 MDes projects, and several M.Tech. and M.Sc. projects. He has published two books, edited 2 conference proceedings, and obtained three National patents. He has applied for one International patent in the area of product design. Professor Ray is attached with several International and National Publishers as a referee. He is also member of the International Development Standing Committee of the International Ergonomics Association. The Concept of creating HWWE platform in India is his brain child and the first HWWE conference was hosted at IDC, IITB, in the year 2001 under his secretariat.

Dr. Rauf Iqbal Associate Professor—Ergonomics and Human Factors Engineering, Prof. In-Charge—Ergonomics Laboratory, Coordinator—Mind to Market Centre, National Institute of Industrial Engineering (NITIE). His academic qualification is M.Sc. in Ergonomics and Work Physiology (Topper, Gold Medalist, Calcutta University) and Ph.D. His areas of expertise are Ergonomics & Human Factors Engineering and Worksystem Design. He has published 39 papers in International and National Journals including book chapter. He had presented 57 papers in International and national conferences. Five scholars have been awarded Ph.D. and five more are currently pursuing their Ph.D. under the guidance of Prof. Rauf Iqbal. He is the paper reviewer of (i) 'Journal of Back and Musculoskeletal Rehabilitation', published by Roessingh Research and Development, Netherlands. (ii) 'Journal of Sports Sciences', published by Taylor and Francis group on behalf of the British Association of Sport and Exercise Sciences, UK. (iii) 'Indian Journal of Biological Sciences' published by Vidyasagar University, West Bengal, and (iv) International Journal of Health Science and wellbeing', Nigeria. He is the member of various national and international committees like member of the Technical Committee for Prime Minister's Shram Awards for the year 2015. Member of Tripartite Awards Committee of Vishwakarma Rashtriya Puraskar (VRP) and National Safety Awards (NSA) by the Ministry of Labour and Employment, Govt. of India, since 2014; member of BRICSplus liaison Sub-Committee for collaborative work (training, research, and conference) on ergonomics among BRICS countries; International Editorial Board member of Journal of Health and Safety at work, published by Tehran University Medical Journal publisher; member of Research Progress Committee, external expert and member of Internal Quality Assurance Cell of SNDT Women's University, Mumbai, etc.

He has Conducted 10 sponsored projects/National studies and more than 50 industrial consultancy studies in the area of Ergonomics, Work-study, and manpower optimization. Recently he has been involved in "Redesigning the palanquin system for use in Mata Vaishno Devi Shrine", funded by the office of the Principal Scientific Advisor to Govt. of India, New Delhi. He is involved in collaborative research and consultancy with various industries and institutes in the area of Ergonomics, Product, and Worksystem Design. He has been organizing conferences and seminars at national and international level.

Dr. Anindya K. Ganguli was born and educated in Calcutta. After graduating from Presidency College, Calcutta, in 1975, he completed his postgraduate studies in Physiology (with specialisation in Work Physiology and Ergonomics) from

Calcutta University in 1977, and undertook research in the Ergonomics Laboratory of the Department of Physiology, Calcutta University under the renowned Prof. R. N. Sen. In 1983, he joined the Occupational Health Service of the Bharat Heavy Electricals Ltd., Tiruchirapalli, as the first ever in-house ergonomist in Indian industry, ultimately heading the Work Physiology and Ergonomics unit there. He grew with the organization in its Occupational Health and Safety journey till his retirement as a Senior Deputy General Manager in 2014. He is a Lead Assessor for the Occupational Health and Safety Management System Standard (OHSAS 18001), and Environment Management System Standard (ISO 14001), and has undertaken numerous ergonomics consultancy assignments in different industries. He is the Chairman of the Sectional Committee on Ergonomics Standards (PGD-15) of the Bureau of Indian Standards (BIS). He served as faculty in Ergonomics for the M.E. (Industrial Safety Engineering) course at the National Institute of Technology (Formerly REC), Tiruchirappalli, and as visiting faculty for the M.Des. course at the Industrial Design Centre, IIT Bombay. He has published 30 scientific papers, (including 12 in foreign journals), has contributed to four books. He has received the BEL-IND Award for the Best Research Paper in Industrial Medicine, and the Sadagopan Memorial Oration Award. Currently, he is a member of the Human Factors and Ergonomics Society (USA), and the President of the Indian Society of Ergonomics.

Vivek Khanzode is Associate Professor at National Institute of Industrial Engineering, Mumbai. His academic credentials include Bachelor's degree in Mechanical Engineering from Walchand College of Engineering, Sangli, and M. Tech. and Ph.D. in Industrial Engineering from IIT Kharagpur. He has been recipient of Director's Silver Medal at M.Tech. program in IIT Kharagpur. He has 5½ years of industrial experience and 14 years of academic experience. He has helped various organizations including several small-scale units to improve productivity using industrial engineering tools and techniques. He regularly conducts niche training programs in the areas of Industrial Engineering, Worksystem Design, Lean Manufacturing, and Industrial Safety Management for practitioners and academicians. He is also involved in collaborative research activities in these areas. Professor Khanzode has published 13 papers in international journals, and presented 23 papers in international and national conferences. One scholar has been awarded Ph.D. under the guidance of Prof. Khanzode and four more are pursuing doctoral research. Three of his papers are included in the ILO database of Hazard and Injury Risk Assessment. Currently he has been involved in redesigning the palanquin system for Mata Vaishno Devi Shrine, a NITIE–IIT Bombay joint project funded by the Office of the Principal Scientific Advisor, Government of India, New Delhi. Professor Khanzode teaches Operations Management, Lean Manufacturing, Simulation Modeling, Facilities and Layout Planning, and Worksystem Design in different postgraduate programs at NITIE.

Part I
Biomechanics

Chapter 1
Impact of Footwear on Gait Parameter

Devika Vipin Vaidya, Rauf Iqbal and Archana Bhatnagar

Abstract A pair of faulty footwear can alter your gait pattern as well as can cause stress on your lower extremity. Study emphasis impact of high heels and flat heels on gait and also highlights pain and aches due to faulty footwear of young female adults. A group of 18 females with mean age, height and weight 22.67 ± 1.49 years, 157.65 ± 6.70 cm and 55.72 ± 10.89 kg respectively were selected for the study. Subjects were allowed to walk at self-selected speed for three test conditions, i.e., barefoot walk, flat heel walk, and high heel walk. Their gait was captured by Qualisys Motion Capture System with Oqus infrared camera (6 no.) Sweden. Speed and stride length decreased whereas stride width and double limb support increased. Consumer perspective while purchasing and using footwear was examined on 90 young females, poor choice of footwear negatively influenced the gait pattern. Footwear design is proposed in the study to reduce stress on lower extremity while acquiring natural gait.

Keywords Gait pattern · Footwear design · Footwear choice · Stride length · Stride width · Double limb support

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1 Introduction

Walking, specifically gait is a basic component of daily living and every individual has a unique gait pattern. Gait analysis is a field of biomechanics which systematically measures, analyze, and assess human walking pattern from initial placement of the heel on the ground to placing same heel on the ground for a second time.

Indian footwear industry ranks second largest in the world [3]. Footwear protects and supports feet during locomotion; footwear selection is one of an important consideration for comfortable walking.

Consumer trends dominate greater sales of female footwear compared to male footwear [3]. Female adults love closet full of footwear be it flats, heels, boots, ballets, sandals, clogs, platforms, wedges, strappy, buckled, lace-ups, peep-toes a woman has desire for all, a great pair of footwear instantly changes their mood for the better. Overall women consider design and fashion rather than health and comfort as their top priorities while purchasing footwear [4].

The purpose of this study was to determine change in gait pattern while wearing flat heel, i.e., flip-flop (1 inch), high heels (4 inch) and comparing it with barefoot with respect to walking speed, stride width, stride length, double limb support, and ground reaction force on young females. Also consumer perspective while buying and discomfort while using footwear was studied.

Study recommends footwear design keeping in mind material, heel height, and pattern for the females who prefer aesthetics over comfort of the footwear. Good design with comfort and aesthetics will add value without compromising health of the well-being.

2 Methodology

The study was carried at the Ergonomics laboratory of National Institute of Industrial Engineering (NITIE), Mumbai. The sample size for the experimental study was 18 females in the age range of 20–30 years and 90 similar participants for descriptive study. The subjects were selected by using purposive sampling method.

An array of six high speed cameras type-OQUS by Qualisys Motion Capture System, Sweden were used to film the participants walking along a pathway.

Thirty-six reflective markers were placed on specific locations of each participant's legs and pelvic region. Markers were placed as close to body and remained stationary thought the study.

Each participant walked barefoot at a self-selected speed to establish a baseline and then in a random order, they walked along the walkway wearing flip-flops and heels for a minute respectively. Each participant followed the same protocol for three testing conditions. The participants were allowed to walk on two force plates (Kistler, Switzerland). Force plate-1 and force plate-2 were stepped by left foot and right foot respectively. Three trials were recorded for each participant by OQUS infrared digital cameras. The best of the trials were considered for analysis. The data was analyzed by Visual 3D software (professional version).

The defining markers placed on the body enabled Visual 3D to track and reconstruct the digital skeleton of the participant. Gait reports were generated for each participant and comparison was made.

ANOVA TEST was performed on kinematic and kinetic gait characteristics to find impact of footwear on walking pattern.

Questionnaires were completed and returned by respondents with respect to their buying behavior of footwear and pains or aches during daily walk. Descriptive statistics was used to analyze consumer perspective for purchasing and using footwear.

3 Results

Mean age, height, and weight of the participants were 22.67 ± 1.49 years, 157.65 ± 6.70 cm, and 55.72 ± 10.89 kg respectively.

Table 1 display's different gait parameters like speed, stride length, stride width; ground reaction force which creates difference among barefoot walk, flat heel walk, and high heel walk.

ANOVA test revealed significant difference among speed (p = 0.00), stride length (p = 0.01) and double limb support (p = 0.00) while walking barefoot, with flat heel and high heel, no significant differences were seen between stride width and ground reaction force ($p < 0.05$)

Consumer perspective revealed 62% women wear flat heel daily as compared to shoes, sandals and heels and 96% women wear heels for occasions. 82% women prefer fashion over comfort of the footwear which leads to pressure on feet altering gait pattern. It was found that 58% women wear semi-hard material cushioning footwear. Cushioning is considered one of the important elements absorbing shock during heel strike. Study reveals that 76% women suffer from foot aching, 48% from shoe bites and 4% from blisters. Shoe bites can occur due to wearing new or ill-fitting of footwear. 79% females suffer from pain in lower extremity. Pain was

Table 1 ANOVA test—gait parameters with respect to footwear's

Gait parameters	*df*	Mean square	*F*	*p* value
Speed	2	0.134	11.535	**0.000**
Stride_length	2	0.090	7.942	**0.001**
Stride_width	2	0.005	0.487	0.617
D_L_S	2	723.463	53.008	**0.000**
GRF_left	2	701.487	0.150	0.861
GRF_right	2	148.679	0.035	0.966

Bold values As values are significant showing the changes addressed in lower back, thighs, knees, calves, and feet. Thereby, footwear can directly influence gait pattern with respect to its design, heel height, cushioning and arch support.

4 Discussion

In the study, speed, stride length significantly decreased from barefoot walk to flat heel to high heels. Speed was the slowest while wearing high heels and double limb support increased significantly while wearing high heels in order to maintain balance. Thus gait pattern changes when wearing flat heel as well as high heel but maximum changes were noted during high heel walk.

Similar study was reported as heel height increases, the females display shorter stride length and step length, wider stride width and increase walking cadence which attributed to a more cautious walking pattern so as to compensate for the elevation and forward shift of the center of gravity, and altered biomechanics of the foot so as to prevent falls and foster postural stability [5].

Other research on five female participants exhibited that wearing high-heeled shoes displayed decrease in stride length and step length [2].

Researcher compared the effect of different heel heights on gait parameters of individuals wearing high heel shoes with low heel shoes or with barefoot. The researcher noted that individuals on high-heeled shoes have shorter stride length and increased walking cadence [1]. High-heeled gait disrupts ideal pattern as reported by [6].

Wearing high heels not only influences gait pattern negatively but also causes pains and aches in lower extremity. High-heeled shoes with an excessive focus on fashion can lead to musculoskeletal diseases such as plantar fasciitis, hallux valgus, ankle sprain, and chronic lower back pain and induce change in the muscles around the knee joint increasing chances of knee osteoarthritis and may increase the risks of back pain and strain injury [4].

Flip-flops have gained a huge market as they are cheap, comfortable, light weight, and convenient to wear and walk. According to American Podiatric Medical Association (APMA) flip-flops are not good for extensive walking as there is no arch support, heel cushioning or shock absorption and can cause foot pain moreover it hardens sole of our feet.

Fig. 1 Proposed footwear design by Author (self-made)

5 Conclusion

Speed and stride length reduces whereas stride width and double limb support increases from barefoot to flat heel to high heels gait pattern.

Different types of footwear alter gait pattern. Maximum change in the gait pattern was noted with high heels, also footwear without heels like flip-flops are not suitable for walking as it does not have arch support.

Footwear choice is made with respect to fashion/aesthetics and not comfort of footwear. Faulty footwear design leads to several feet problems.

Finding the right pair of footwear seems to be a simple task, but with the advances in material and production, one should be careful while making choice of footwear. During procurement of shoes it is to be noted that the footwear bends at the toe box, but not too flexible, there should be a sufficient arch support and incase of heels, a chunky heel less than 2 inches high should be chosen.

In order to have natural and comfortable walk, footwear design was proposed in this study as shown in Fig. 1 that will help in minimizing stress on lower extremity.

Design was made considering foot bed, arch support, soft sole, more contact area of heel, soft lining of upper, breathability of material and comfort along with aesthetics. Stage one involved making suitable last (mould) for the footwear, subsequently various materials were collected and final design was made. Lycra material was used for upper part of the footwear bands to avoid shoe bite, Epdm material which has dual density and softness was used for insole, pattern was selected to give complete grip to the feet with good heel height.

Proposed footwear envisages aesthetic design with comfortable-natural gait without stress on lower body.

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Chapter 2
Characteristics of Gait Variability Among Healthy Indian Construction Workers During Different Load Carrying Modes

Arundhati Guha Thakurta, Rauf Iqbal, H.V. Bhasin, Amitabha De, Vivek Khanzode and Shreya Maulik

Abstract Compared to work-related musculoskeletal disorders of the upper extremity and lower back area, much less investigative focus has been found on the prevention of lower limb musculoskeletal disorders and injury (LLD) in the workplace. A higher incidence of musculoskeletal injuries in lower extremities when carrying a heavy load during daily activities was found among Indian construction workers. The objective of this study was to examine the changes in temporal and distal gait parameters of healthy Indian men and women construction workers with different modes of load carriage. Five healthy male and five female construction workers were selected to walk at self-selected speed along a 7 m walkway, crossing two Kistler force platforms with unloaded and different loaded (15 kg) conditions. Indian males and females displayed significantly different gait patterns under all load conditions while the changes were relatively small in males. The results also indicated that the walking patterns of both the male and female subjects among the Indian construction labours were affected while carrying loads in different modes. It was found that due to differences in the ability to carry heavy loads in different modes, females are more prone to injuries compared to males and so considering the biological differences load carriage task should be assigned carefully to the female labours.

Keywords Stride length/stride width · Load carriage, swing time, double limb support · Walking speed

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1 Introduction

Awkward postures, dreary work, or handling heavy loads are some of the risk factors that contribute to musculoskeletal disorders (MSD) and work-related disorders are mostly cumulative due to repeated exposure to loads at work over a long time period and account for absenteeism from the workplace in many occupational groups [5]. However, much less attention has been given to the public health of lower limb musculoskeletal disorders and injuries relative to work-related MSD of the upper extremities and lower back area [2]. The manner of walking with normal speed of about 2.5–3 mph is defined as normal human gait [7]. It maintains a sequence of movement of the two legs containing two distinct phases, stance phase and swing phase [12].

1.1 Effects of Load on Gait

Nowadays, human motion analysis has received a lot of research attention and is used in load determination and effect [3]. Load carriage tasks have the probability to cause s variety of injuries fractures of knee, ankle, and low back associated with slips and falls [13]. Specifically, the effects of different ways of carrying external loads on gait were being measured as load carriage is a very common daily activity at home and in the workplace and is a common cause of injuries, including those of the knee and lower back [8]. Therefore, it is important to understand the effects of different modes of load carriage on human gait pattern [10]. There are many previous studies that characterize the nature of gait and the effects that external loads have on gait [9] and found that the swing phase of gait decreases when carrying a load, while the stance is not much affected by loads [9, 14].

Few studies compared the impact of different modes of load carriage on human gait. Women in daily work were found to have a higher incidence of musculoskeletal injuries due to their structure when carrying a load during their daily activities [11, 15]. Various load configurations for healthy men have been examined, but such study on women is scarce. This study examined the changes in gait patterns of both healthy men and women in India while carrying load in different modes.

2 Objectives

This study aims to quantify the gait pattern differences between unloaded and different types of loaded walking in between Indian men and women and classify these differences using simple analytical models.

3 Methods

Five healthy female and five healthy male Indian construction workers without any musculoskeletal problems in the spine and legs were selected for this study. An informed consent of each participant was taken before taking part in the experiment. Their ages ranged from 20 to 25 years. The study obtained ethics approval of the National Institute of Industrial Engineering (NITIE) Ethics committee, Mumbai, India. Thirty six reflective markers were placed on specific locations of each volunteer's legs and pelvic region. The defining reflective markers, which enabled Visual 3D to reconstruct the digital skeleton of the volunteers. An array of six high speed cameras type-OQUS by Qualisys Motion Capture System, Sweden were used to film the volunteers walking along a 7 m walkway. Each volunteer first walked at their self-selected speed without any load. This was used to establish a baseline and then, in random order, they walked along the walkway with a 15-kg cubical load box of 40 cm × 40 cm × 16 cm on the head, across one shoulder and separately on left and right hand (frontal plane) and pulling and pushing of load against the ground with a wheel less trolley were also considered. Each volunteer followed the same protocol for the four testing conditions. The volunteers were allowed to walk on both the force plates (Kistler, Switzerland). Force plate-1 and force plate-2 were stepped by left foot and right foot respectively. The volunteers were asked to walk for 60 s during which four trials were recorded by the OQUS infrared digital cameras. The average of the trials was considered for analysis to minimize the experimental error and bias.

4 Results and Discussion

The volunteers (male and females) were selected between the age group of 20–25 years for performing the task of load carrying in different modes which were purposely selected. The demographic data like height, weight, etc. has been presented in Table 1. The average basal metabolic rate (BMI) of both males and females were within the cut off range, as normal cut off values for BMI was 23 kg/m^2 for both sexes [16]. The demographic were used to determine the gait characteristics of an individual.

In Table 2, the average stride length was normally found to decrease with loaded condition compared to unloaded condition. It decreased more during head load in females and while pulling the load against the ground in males. The stride length decreases with the decrease in speed during loaded condition. The stride width was maximum during pushing the load both for females and male followed by head load. The cadence (steps/min) decreases with the load conditions and it was minimum during pulling the load. The gait speed (km/h) was minimum while pulling the load in females and in males. An increase in double support and a decrease in preferred stride length as carried load increased has been noted [1] but it is found that with

Table 1 General information of the volunteers

Variables	Gender	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Hip circumference (cm)	Pelvis depth (cm)
Mean	Females	22.3	157.5	58.5	22.3	96.5	12.7
	Males	24.3	165.8	60.2	22.9	92.5	11.0
Standard deviation	Females	1.64	7.42	8.65	3.20	6.12	1.80
	Males	1.44	5.68	7.23	3.20	7.42	1.50
Range		20–25	147.7–171.0	41.5–69.9	17.61–27.65	86–103.5	10.3–16.5

Mean ± SD

Table 2 Effect of different load carriage modes on basic gait parameters

↓Load pattern/gait variables→	Stride length (cm)	Stride width (cm)	Cadence (steps/min)	Speed (km/h)
Free walk				
Female	130 ± 0.08	11.0 ± 0.02	124 ± 9.50	5.04 ± 0.14
Male	140 ± 0.08	13.9 ± 0.04	132 ± 8.70	5.76 ± 0.19
Head				
Female	110 ± 0.22	12.6 ± 0.03	107 ± 5.30	4.32 ± 0.17
Male	120 ± 2.30	14.5 ± 0.05	110 ± 4.40	4.68 ± 0.16
Right hand				
Female	120 ± 0.12	11.0 ± 0.02	115 ± 8.30	4.68 ± 0.18
Male	120 ± 2.30	13.6 ± 0.03	118 ± 6.50	5.04 ± 0.12
Left hand				
Female	120 ± 0.26	11.9 ± 0.02	116 ± 6.40	4.68 ± 0.11
Male	120 ± 2.30	12.8 ± 0.03	118 ± 7.80	5.04 ± 0.08
Shoulder				
Female	120 ± 0.12	11.8 ± 0.02	119 ± 4.50	4.68 ± 0.14
Male	130 ± 0.21	13.2 ± 0.03	118 ± 3.30	5.04 ± 0.25
Pushing against the ground				
Female	130 ± 0.37	14.0 ± 0.04	110 ± 7.20	4.82 ± 2.30
Male	130 ± 0.08	15.4 ± 0.02	115 ± 9.50	5.15 ± 1.30
Pulling against the ground				
Female	118 ± 2.30	14.5 ± 0.05	105 ± 5.20	4.32 ± 0.16
Male	124 ± 0.22	12.6 ± 0.03	107 ± 5.70	4.68 ± 0.17

Mean ± SD

change in load carriage mode both the parameters changes significantly. With increasing speed also the stride length increases [18]. In Table 3, the swing time found to decrease while carrying load and was minimum while carrying head load and load pulling for both males and females, as speed decreases with the load condition and this is in accordance with the study of Beauchet et al. [2], whereas double limb support time increased during loaded condition. Single-limb support

Table 3 Effect of different load carriage modes on selected gait parameters (stance, swing and cycle time, double limb support)

Load pattern	Gender	Stance time (s)		Swing time (s)		Double support (s)	Cycle time (s)	Double support (no of times)
		Left	Right	Left	Right			
Free Walk	Female	0.626 ± 0.052	0.624 ± 0.055	0.412 ± 0.028	0.412 ± 0.015	0.5 ± 0.27	1.2 ± 0.31	9.0 ± 1.06
	Male	0.691 ± 0.051	0.680 ± 0.018	0.471 ± 0.053	0.452 ± 0.046	0.3 ± 0.76	1.0 ± 0.27	7.0 ± 1.25
Head	Female	0.570 ± 0.073	0.570 ± 0.032	0.360 ± 0.018	0.385 ± 0.051	0.2 ± 0.06	1.2 ± 0.10	15.0 ± 5.33
	Male	0.597 ± 0.028	0.592 ± 0.032	0.425 ± 0.028	0.418 ± 0.070	0.1 ± 0.09	1.1 ± 0.50	14.0 ± 3.55
Right Hand	Female	0.536 ± 0.019	0.540 ± 0.037	0.454 ± 0.030	0.462 ± 0.053	0.2 ± 0.03	1.1 ± 0.06	9.0 ± 3.31
	Male	0.608 ± 0.027	0.594 ± 0.030	0.420 ± 0.038	0.420 ± 0.032	0.3 ± 0.76	1.0 ± 0.27	8.0 ± 2.30
Left Hand	Female	0.571 ± 0.056	0.562 ± 0.068	0.419 ± 0.056	0.422 ± 0.064	0.2 ± 0.56	1.1 ± 0.11	9.0 ± 2.11
	Male	0.494 ± 0.068	0.500 ± 0.073	0.396 ± 0.051	0.377 ± 0.070	0.3 ± 0.26	1.0 ± 0.67	8.0 ± 1.30
Shoulder	Female	0.673 ± 0.028	0.678 ± 0.018	0.453 ± 0.030	0.448 ± 0.051	0.2 ± 0.02	1.0 ± 0.06	12.0 ± 5.68
	Male	0.668 ± 0.053	0.660 ± 0.015	0.462 ± 0.055	0.448 ± 0.032	0.3 ± 0.15	1.1 ± 0.07	14 ± 0.05
Push	Female	0.604 ± 0.053	0.668 ± 0.054	0.434 ± 0.043	0.435 ± 0.28	0.2 ± 0.07	1.0 ± 0.25	9.0 ± 0.04
	Male	0.652 ± 0.056	0.626 ± 0.028	0.400 ± 0.024	0.417 ± 0.036	0.3 ± 5.97	1.0 ± 0.05	8.0 ± 2.27
Pull	Female	0.670 ± 0.053	0.592 ± 0.053	0.425 ± 0.043	0.418 ± 0.024	0.1 ± 0.09	1.2 ± 0.50	17.0 ± 3.55
	Male	0.597 ± 0.056	0.670 ± 0.034	0.340 ± 0.056	0.335 ± 0.056	0.2 ± 0.06	1.1 ± 0.10	15.0 ± 5.33

Mean ± SD

time increased and double limb support time decreased on both legs with each increase in speed [17]. Cycle times were almost same for all the modes of load but slightly greater during pulling the load and head load. Number of time of double limb support was found to be maximum during pulling the load carrying head load. Females exhibit lower extremity kinematic patterns that differ from males. Female kinematic patterns may contribute to an increased risk for lower extremity injury [6].

Statistical analyses were performed using SPSS 18. For each subject the average and the standard deviation of the parameters were determined. Comparisons using a one-way ANOVA with repeated measures were conducted to examine differences between parameters during different conditions at $p < 0.05$. Changes in selected gait parameters were noted while walking with different load condition.. This is in accordance with the results of the study carried out by Connolly et al. [4].

There are some limitations in this study. The selected walking distance in the laboratory was small compared to their actual paving walkway. The influence of fatigue on gait pattern during different modes of load carriage would make a valuable contribution.

5 Conclusion

In developing countries like India, construction labours, both males and females, of different age groups engaged in manual load handling carries heavy loads in different ways depending on the type of load to be carried. The results of the study indicated that the males and females exhibited notably different gait patterns in all modes of load carriage. Females were substantially affected than males, thereby signifying a greater sensitivity to all the modes of load carriages. Vigilant inspection should be carried out while selecting the mode of load carriage and the magnitude of the load, specially, when carried by the females because of the greater impact of their physiological as well as bio-mechanical influences and the additional involuntary stresses experienced during locomotion compared to males. The results would also have implications on carrying load in a variety of industrial situations and environments.

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Part II
Musculo Skeletal Disorders

Chapter 3
A Study on Agony of Indian Percussionists

W. Mishra, Amitabha De, Rauf Iqbal, Vivek Khanzode, S. Gangopadhyay and A.M. Chandra

Abstract The present study was undertaken to assess the causal risk factors for discomfort among Indian percussionists (Tabla players) and to suggest if possible, any recommendation strategies. Quick Exposure Check (QEC) was used to evaluate the exposure to risk factors and a modified questionnaire was used to identify the risk factors. The scores from QEC showed that back and shoulder of Tabla players were at very high risks, neck at high risks category and wrist at moderate risks. Another questionnaire was administered to assess the causal factors for PRMDs. Subsequently, factor analysis was carried out on the causal factors. Consequently, two factors emerged with higher factor loadings. Factor 1 comprised of long practice sessions, tour, insufficient rest, performance frequency and stress. Factor 2 comprised of lack of flexibility, poor posture, and technical flaws. Based on the results some recommendation strategy was suggested to minimize PRMDs.

Keywords Musculoskeletal disorders · Risk factors · Tabla · Percussionists · PRMDs · Quick exposure check

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1 Background

Playing-related musculoskeletal disorders are found to be multifactorial in nature [21, 22]. Therefore, it becomes important to examine the factors on causation of disorders. Literature revealed that there are intrinsic and extrinsic factors for the causation of disorders. Some of the intrinsic factors include age, [6] gender [2, 13, 17] hyper-mobility, size [12, 19]. The extrinsic factors mainly include duration of playing, technique of playing, and awkward posture. Studies have shown that the practice time in hours, a sudden increase in playing intensity are important factors that can contribute to upper extremity disorders [7, 23]. It has also been reported that taking breaks during practice sessions and warming up before practicing reduce the risk [23]. Playing for long and intense periods of practice in uncomfortable postures [20] leads to PRMDs. Psychosocial factors such as stress were also reported to be one of the major contributing factors [23]. Hence, it can be seen that multiple risk factors are responsible for causation of PRMDs. These PRMDs are prevalent in all types of instrumental musicians [15]. However, studies have indicated that among all instrumental musicians percussionist are at higher risk for PRMDs [18]. Among Indian percussion instruments, it has been reported that Tabla players are found to suffer from PRMDs [16]. In view of the above, this study was undertaken to assess the causal risk factors for discomfort among Indian percussionists (Tabla players) and to suggest if possible recommendation strategies.

2 Methodology

The study was approved by the ethics committee (Institutional Human Ethics Committee, Department of Physiology). For the study professional Tabla players having minimum of 5 years of experience were chosen for the study. Signed inform consents were obtained from the volunteers. Quick Exposure Check (QEC) was administered to all to Tabla players [3] to capture exposure to risk factors. QEC assesses the exposure of the four body areas at greatest risk to the most important risk factors. These scores represent a hypothetical relationship between the increased level of exposure and potential health outcomes. Another, questionnaire was adapted from Ackerman [1] and modified according to the requirement of the study was also administered. The original questionnaire consisted of 37 items with sub items in between. Out of these 37 questions, those questions which met the objectives of the study were selected and added to modified questionnaire. The questionnaire was on a ten-point scale where the impact of contributory risk factors in causation of PRMDs was recorded. Akerman, however, did not check validity and reliability. Therefore, the validity of the questionnaire was checked by experts' opinion while the reliability was reported by evaluating Cronbach alpha value.

3 Results

The results of the study are depicted below. Tables 1, 2, 3, 4, 5 and 6 reveal the major results of the study.

Table 1 reveals the scores of back, shoulder/arm, wrist/hand and neck. Back and shoulder/arm were found to be at very high risk while wrist/hand at moderate risk and neck at high risk.

Table 2 showed total item statistics. Cronbach alpha if item deleted reveals that all values are more than 0.75. The lowest value was for insufficient rest 0.75.

The results of Cronbach alpha are presented in Table 3. The Cronbach alpha for eight-item questionnaire was found to be 0.79 which is acceptable [8].

Table 1 Scores of QEC

Body parts	Mean SD (±)	Remarks	Reference range
Back	34.30 (2.61)	Very high	29–40
Shoulder/arm	44.83 (4.40)	Very high	41–56
Wrist/hand	24.5 (2.98)	Moderate	21–30
Neck	13.26 (2.02)	High	12–14

Table 2 Results of Cronbach alpha—internal consistency of questionnaire

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
Long practice session	42.41	146.11	0.38	0.79
Insufficient rest	41.22	138.28	0.63	0.75
Performance frequency	42.34	137.41	0.51	0.77
Poor posture	40.84	136.18	0.5	0.77
Lack of fitness and flexibility	40.72	134.75	0.56	0.76
Technical flaws	40.73	127.41	0.54	0.76
Touring	42.16	133.97	0.42	0.79
Stress	41.25	136.20	0.52	0.77

Table 3 Reliability statistics

Cronbach's alpha	No of items
0.79	8

Table 4 Results of factor analysis—total variance explained

Component	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)
1	3.4	42.07	42.07	3.36	42.07	42.07	2.27	28.4	28.38
2	1.1	14.21	56.29	1.13	14.21	56.29	2.23	27.9	56.29
3	0.8	10.60	66.89						
4	0.73	9.12	76.01						
5	0.59	7.40	83.42						
6	0.50	6.25	89.68						
7	0.49	6.18	95.86						
8	0.33	4.13	100.00						

Table 5 Rotated component matrixes

Components	Factor loadings (FL)	
	Factor 1	Factor 2
Insufficient rest	0.733	–
Long practice session	0.716	–
Touring	0.674	–
Stress	0.634	–
Performance frequency	0.526	–
Lack of fitness and flexibility	–	0.825
Technical flaws	–	0.790
Poor posture	–	0.754

Table 6 Responses after training

Sr. no	Questions	No of positive response
1	Have you followed the exercise regime taught to you?	70
2	Have you been able to do the exercises regularly in last 8 weeks?	60
3	Do you feel better after doing these exercises	50
4	Have you adapted your style of sitting with back rest in practice sessions	50
5	Are you following the guidelines of load handling?	40
6	Has the training session helped you?	60

Table 4 presents the eigen values associated with each factor before extraction, after extraction, and after rotation. The extraction method was Principal Component Regression (PCR). The total variance explained is 56.29%.

Table 5 presents rotated component matrix. It can be seen that Factor 1 comprises of long practice sessions, tour, insufficient rest, performance frequency, and stress. Factor 2 comprises of lack of flexibility, poor posture, and technical flaws. Factor 1: occupational related factors (ORF) and Factor 2 was named as Individual factors (IF).

Table 6 represents the responses after 8-week training. 70% followed the exercises. 60% reported that the training session helped.

4 Discussion

In order to identify the exposure to risks, QEC was administered. Results of Quick Exposure Check (QEC) showed that back and shoulder were at very high risks, neck at high risks category and wrist at moderate risks for Tabla players (Table 1). The findings were similar to previous studies [9–11].

For identifying the major risk factors a ten-point questionnaire was administered. The questionnaire developed by Ackermann and Driscoll [1] was modified and used in the study. The internal consistency of modified questionnaire was determined by Cronbach alpha. Cronbach alpha (Table 2) value was observed to be 0.79 which suggested that internal consistency of modified questionnaire was acceptable. Ackerman however did not report the internal consistency of his questionnaire. In order to explore the construct validity and underlying dimensions of the questionnaire, factor analysis, principal component analysis with varimax rotation, eigen value at least greater than 1 was used. The cutoff point for item factor loading factor was 0.40.

Consequently, it was evident from Table 5 that the highest loading was on lack of flexibility, followed by poor posture and technical flaws. Studies have reported that lack of fitness; stress, poor posture, insufficient rest, performance frequency, and faulty playing technique are risk factors towards PRMDs [5, 18]. However, the responses were slightly different as Davies involved several group of instrumentalists where percentage of percussionist was less (6.7%).

But this substantiates that musicians suffer from similar risk factors. As lack of flexibility, poor posture and technical flaws are related to individual habits and nature so they are called individual risk factors. While factor 1 comprised of long practice session, tour, insufficient rest, performance frequency, and stress. These components are related to Tabla players' task/occupation. Hence, this was named as occupation-related risk factors.

Based on the findings some recommendation strategies were given to Tabla players. Since components of Factor 2 had higher loadings, therefore recommendation strategy was given on same lines. The suggested recommendation strategies were regular breaks during practice session, exercise specifically back exercises, proper load carrying (instrument carrying), and sitting with back rest while practicing was encouraged. A physiotherapist was appointed who gave training session on back exercises and load handling. A follow up was done after 8 weeks to find if they practiced the exercises and find the effect. The results revealed that 70% followed the exercise regime. 60% managed to do the exercise. 50% use back rest in practice session 60% found the session helpful. It shows that the discomfort reduced. The findings corroborated with previous studies which have indicated that tailored made training program catering to musicians prevents PRMDs [4, 14]. However, this needs to be carried on larger sample size.

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Chapter 4
Prevalence of Upper Limb Disorders and Investigation of Risk Factors Among Commercial Kitchen Male Workers in South India

S. Shankar, M. Shanmugam and J. Srinivasan

Abstract Studies have reported that workers in the kitchen industry were at high risk of work-related musculoskeletal disorders (MSD) due to their occupation. This work aimed to determine the prevalence of upper limb disorders and investigated the risk factors among the male kitchen workers through a structured self-administered questionnaire survey among 114 male kitchen workers from nine college hostels in Western Tamil Nadu, India. Statistical analyses were performed to describe the demographic factors and its association with disorders. The prevalence of shoulder discomfort was highly associated with the different work types ($p = 0.002$), work experience ($p = 0.022$), and age groups ($p = 0.011$). The results indicated that health factors, ergonomics intervention, and engineering control on working conditions of the industry might be considered to reduce MSD.

Keywords Kitchen workers · Musculoskeletal disorder · Upper limb disorders · Work risk factors

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1 Introduction

Upper limb musculoskeletal disorders were one of the major discomfort level mainly associated with the body regions like shoulder, neck, elbow, wrist, or hand [1]. The factors like repetition of work, awkward postures, or static shoulder loads and other workplace factors were evaluated as the evidence of positive association with upper limb disorders and the risk for Carpal Tunnel Syndrome, and neck/shoulder MSDs [2]. Repetitive trauma disorders of the upper extremity were the major cause of loss of work in many hand-intensive industries [3]. Physical factors associated with musculoskeletal pain were, long working hours and working in awkward postures or frequently engaging in repetitive hand movements [4].

The kitchen workers were reported as one of the highest risk occupational group for work-related injuries because of their work nature and the types of materials handled [5]. Kitchen work includes many physical and psychosocial load factors and many factors leading to MSD [6]. An investigation for the clear assessment on the association of risk factors and upper limb disorders among male kitchen workers was performed in this study. The main purpose of this study was to evaluate, the prevalence of upper limb musculoskeletal disorders among male kitchen workers and relationship between ergonomic risk factors and disorders.

2 Methodology

2.1 Study Population

A cross-sectional study was conducted on 114 male kitchen workers from nine hostels in a college campus located in the western part of Tamil Nadu, India. Study population in different age groups from 19 to 55 was investigated. The principal task of kitchen workers in the college hostels was to prepare food for breakfast, lunch, and dinner for about 600–700 students at regular times. All participants were informed regarding the nature of study.

2.2 Workplace

The food items prepared in the hostel kitchen, which requires more muscular activities, were dosa, idly, chapatti, parotta, rice items. The activities before the preparation of food were grating, chopping, peeling, kneading, mixing, stirring, etc. The menu-based preparation of food was followed throughout the year in all hostels. During the working hours, the factors like working environment, work nature were observed.

2.3 Data Collection and Analysis

A structured self-administered questionnaire was conducted, among the various categories of kitchen workers. This questionnaire included socio-demographic data, occupational characteristics, and questions related to musculoskeletal symptoms similar to some studies [7]. The frequency of discomfort, severity, and the intensity of disorders were measured by a four-point Likert scale. Statistical analysis was performed with Statistical Package for Social Sciences (version 20.0).

3 Results

The study population was 114 out of 120 male kitchen workers. Descriptive statistics for socio-demographic information were presented in Table 1. Among all kitchen workers 21.1% were chief cooks, 61.4% were assistant cooks and 17.5% were kitchen aids. Majority (68.4%) of the study population were ≤ 25 year old with a mean age of 26.4 ± 7.7 (range 19–55), mean working experience as 7.8 years'. The daily workload was to cook for around 600 ± 100 students. It was determined that 19.3% of the participants had been working more than 10 years and 66.7% of them had been working for less than 5 years.

Table 1 Demographic characteristics of the participants (n = 114)

Demographic variables	Chief cooks		Assistant cooks		Kitchen aids	
	n	%	*n*	%	*n*	%
Age (years)						
≤ 25	4	5.1	60	7.9	14	17.9
26–40	14	63.6	8	36.4	0	0
≥ 41	6	42.9	2	14.3	6	42.9
Marital status						
Married	16	66.7	2	8.3	6	25
Single	8	8.9	68	75.6	14	15.6
Cigarette smoking						
Yes	0	0	8	57.1	6	42.9
No	24	24	62	62	14	14
Total work experience (years)						
≤ 5	0	0	60	78.9	16	21.1
6–10	4	25	8	50	4	25
≥ 10	20	90.9	2	9.1	0	0
Excessive force during cooking						
Yes	24	30.8	54	69.2	0	0
No	0	0	16	44.4	20	55.6

The major work tasks of the male kitchen workers were to prepare rice, dosa, chapatti, parotta, gravy, and other side dishes. The work load will be distributed as; the chief cooks involved in the preparation of rice and gravy items; assistant cooks involved in the preparation of dosa, chapatti, and other recipes; kitchen aids involved in the pre-preparation of food items, transportation, distribution, and serving of food. There were two breaks during the day: a 2 h after breakfast preparation and 2 h after lunch preparation. The majority of them (82.5%) involved in prolonged standing, (83.3%) repetitive motion, (82.5%) awkward posture and (89.5%) lifting/pulling the heavy objects during cooking.

3.1 Prevalence of Shoulder, Finger/Wrist, Neck Disorder and Its Association with Risk Factors

Totally 62.3% of the kitchen workers reported shoulder disorders. The prevalence (%) of upper limb disorders among male kitchen workers by different work category was shown in Table 2 and it shows that chief cooks had high ratio of shoulder disorders (79.2%) than other categories of workers. 6–10 years of work experience group had higher prevalence (87.5%) than other groups (Table 3). Table 4 shows the prevalence (%) of upper limb disorders among male kitchen workers by different age groups. 92.9% of the upper age group workers (≥ 41 age group) reported shoulder disorder ($p < 0.05$). Table 5 determined adjusted OR values of the factors that associated with the shoulder disorders or shoulder girdle pain and neck disorders among male kitchen workers by logistic regression analyses.

43.9% of the kitchen workers reported finger/wrist disorders. Table 2 shows 50% assistant cooks experienced finger/wrist disorders than other two work categories. ≥ 41 years of age groups experienced highest rate of finger/wrist disorders with the prevalence of 62.5 and 57.1%, respectively (Tables 3 and 4). Individuals with greater than 10 years of work experience were significantly associated with upper limb disorders. About 38.6% of the kitchen workers reported neck disorders. The highest prevalence of neck disorders of 48.6% were reported among assistant cooks (Table 2) and it was statistically significant.

Table 2 Prevalence (%) of upper limb disorders by different work category

Body parts	Chief cooks	Assistant cooks	Kitchen aids	Chi-square	p*
Shoulder	79.2	65.7	30	12.136	0.002
Neck	16.7	48.6	30	8.433	0.015
Finger/wrist	45.8	50	20	5.734	0.570

*$p < 0.05$ is statistically significant

Table 3 Prevalence (%) of upper limb disorders among male workers by experience (years)

Body parts	≤ 5 years	6–10 years	≥ 10 years	Chi-square	*p* value*
Shoulder	53.9	87.5	72.7	7.600	0.022
Neck	43.4	37.5	22.7	3.092	0.213
Finger/wrist	43.4	62.5	31.8	3.599	0.169

*$p < 0.05$ is statistically significant

Table 4 Prevalence (%) of upper limb disorders among male kitchen workers by age group (years)

Body parts	≤ 25 group	26–40 group	≥ 41 group	Chi-square	*p* value*
Shoulder	53.8	72.7	92.9	8.956	0.011
Neck	35.9	31.8	64.3	4.565	0.102
Finger/wrist	39.7	50.0	57.1	1.877	0.391

*$p < 0.05$ is statistically significant

Table 5 Factors associated with the shoulder disorders, finger/wrist disorders, and neck disorders among Male kitchen workers in logistic regression analyses

Disorders	Risk factors		Subjects (*n*)	Reported disorders (*n*)	Prevalence (%)	Logistic model, adjusted ORs[a] OR (95% CI)
Shoulder disorders	Regular exercise	Yes	90	52	57.8	1
		No	24	19	79.2	6.952 (1.053–45.913)
	Repetitive work	No	19	1	5.3	1
		Yes	95	70	73.7	0.008 (0.001–0.085)
Neck disorder	Age (years)	≤ 25	78	28	35.9	1
		26–40	22	7	31.8	0.665 (0.160–2.759)
		≥ 41	14	9	64.3	0.089 (0.017–0.459)
	Total work experience (years)	≤ 5	76	33	43.4	1
		6–10	16	6	37.5	3.090 (0.83–11.501)
		≥ 10	22	5	22.7	13.862 (2.566–74.868)
	Repetitive work	No	19	1	5.3	1
		Yes	95	43	45.3	0.065 (0.005–0.890)

[a]Each OR is adjusted with other risk factors

4 Discussion

This study investigated the prevalence of upper limb disorders and assessed the risk factors among male kitchen workers. Highest prevalence of discomfort and disorders were reported on shoulder region than other upper limb regions. The results of the study revealed that the major complaints among male kitchen workers were shoulder pain (62.3%), finger/wrist pain (43.9%), and neck pain (38.6%). Shoulder pain was reported as most common and found to be statistically significant for almost all groups (age, experience, different job type).

In a similar work, it was observed that there was a high prevalence of symptoms in the neck, shoulders, arms, and lower back among cooks, by evaluating exposure-response relationship between the cumulative duration of cooking work and the symptoms [8]. So far 80% of workers in canteen kitchens reported problems in the neck and shoulder area [9]. Other occupations too reported shoulder, neck, back, elbow as the prevalent disorders [10] due to various risk factors like repetitive work, excessive force, and heavy lifting similar to the findings in our study. The occurrence of tension neck syndrome was 6.2% among slaughterhouse workers; 27.8% among shop assistants, and 37.5% among factory workers doing repetitive tasks [11]. The occurrence of tenosynovitis and peritendinitis of the wrist and forearm was also found to be 4.4% among slaughterhouse workers, 18.3% among scissor makers, 13.5% among shop assistants, but 55.9% among workers doing repetitive tasks [11].

Gallagher and Heberger [12] reported that interaction of force and repetition causes the musculoskeletal disorder risk. Here both chief cooks and assistant cooks were involved in repetitive works irrespective of the work type. It was confirmed that kitchen aids were suffering less upper limb disorders than chief cooks and assistant cooks. Apart from the college hostel kitchens, this study was not conducted in roadside hotels, restaurants. Despite of the above limitations, this study confirms the existence of upper limb disorders among male kitchen workers. Many studies investigated both the ergonomic aspects and the productivity aspects to reduce their occupational risk factors and in preventing musculoskeletal disorders [13]. The present study recommends in preferring ergonomics intervention and proper working procedures to be formulated to the kitchen workers.

5 Conclusions

This study determined that male kitchen workers were victims of upper limb disorders because of monotonous working condition, work-related and health-related factors. Results infer that there is a prevalence of shoulder pain (62.3%), finger/wrist pain (43.9%), neck pain (38.6%), and elbows (31.6%). The assessment of risk factors was also evaluated and upper limb disorders were found to be associated with age factors, years of experience, repetitive work, and excessive work load. These results could be considered for future intervention and policies on working conditions in the kitchen industry, which may reduce the work-related hazards.

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Chapter 5
Effect of Occupational Factors on Musculoskeletal Disorders of the Insurance Office Employees: A Case Study

Harbir Singh and Lakhwinder Pal Singh

Abstract *Introduction*: The job of insurance employees demands prolonged sitting in the office and they are overworked, which can cause musculoskeletal pain through constant stress on the musculoskeletal system. *Objective*: The aim of the study is to estimate the prevalence of musculoskeletal disorders among insurance office employees and to analyze the effect of the occupational factors on the prevalence of musculoskeletal disorders. *Method*: The survey was carried out at various insurance offices in Punjab (India). The population consists of 182 insurance office employees is studied using questionnaire on duration of office work, frequency of rest break, daily travelling hours, work place layout and musculoskeletal symptoms. *Results*: The prevalence of musculoskeletal symptoms in the neck, shoulders, wrists, upper back, lower back and forearm were 58.2, 38.4, 13.1, 28.5, 46.1 and 7.6%, respectively. Frequency of rest break once in more than 4 h was strongly associated with all MSD's in all body regions. The travelling hours of more than 3 h/day related to work is also associated with upper back pain and low back pain. *Conclusion*: The musculoskeletal symptoms are associated strongly with frequency of rest break, travelling time for work and perception of workplace ergonomics. A high prevalence of musculoskeletal symptoms were observed in neck, lower back, shoulder, and lower back pain among insurance office employees.

Keywords Musculoskeletal disorders · Occupational factors · Insurance office

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1 Introduction

Work-related musculoskeletal symptoms (WMS) are a major health issue in many occupations all over the world [22]. Extensive research has been conducted on these musculoskeletal problems in different occupational groups such as office workers, bus drivers, cleaners, and sewing machine operators [5, 8, 26, 29]. Working in the office environment is widely known to be associated with musculoskeletal symptoms, particularly in the neck, upper extremity and low back regions [16, 17, 23]. Musculoskeletal diseases are a major cause of workers' compensation, medical expenses, sick leave and productivity losses [2, 11, 19, 20]. Long working hours, static postures poor office ergonomics and repetitive nature of work were identified as some of the risk factors leading to pain and discomfort [4, 6, 27]. The office workers frequently perform other physical activities in their normal working day, including lifting, bending, twisting, reaching and climbing stairs, which are the primary risk factors for the persistence of musculoskeletal symptoms [3, 15, 25]. Individual, physical and organizational factors are reported to play an important role in the development of work-related musculoskeletal disorders (WMSD) [24]. Risk factors for MSD include demographic, organizational and physical aspects of [7–9, 13]. Prolonged sitting at suboptimal workstations is associated with musculoskeletal dysfunction [1, 14, 21]. The current study aims to (1) examine the prevalence of MSD among insurance office employees (2) to evaluate the effect of the occupational factors on the prevalence of musculoskeletal disorders.

2 Method

The study population consisted of 182 office workers of different insurance companies located at Punjab. This study used a self-administered questionnaire that involved information on the respondent's individual characteristics, physical and occupational risk factors, general health status, and occurrence of musculoskeletal complaints. Chi-square test and logistic regression analysis was performed with the significance level of $p < 0.05$ to evaluate the influence of occupational factors on the occurrence and consequences of musculoskeletal complaints.

3 Results

Table 1 indicates that the distribution of the subjects in different categories according to explanatory variables like gender, age, BMI, working h/day, rest break frequency, daily travelling hours. As shown in Table 2, the predominant prevalence of MSD is in body region neck (58.2%) and lower back (46.1%). The other affected body regions of insurance office employees are shoulders (38.4%) and upper back

Table 1 Distribution of the subjects in different categories according to explanatory variables

Explanatory variables	*N*	%
Male	155	85
Female	27	15
Age (in years)		
25–30	38	21
31–35	50	27
36–40	16	9
41–45	16	9
>45	62	34
BMI		
<18	2	1
18–25	64	35
26–30	100	55
<30	16	9
Working h/day		
>6 h	6	3
7–8 h	110	61
>8 h	66	36
Rest break frequency		
Once in <2 h	64	35
2–4 h	53	29
>4 h	65	36
Travelling h/day		
>1 h	103	57
1–3	52	29
>3	27	14

Table 2 Prevalence of MSD in different body regions of insurance office employees (n = 182)

Body regions	*N*	%
Neck	106	58.2
Shoulders	70	38.4
Upper back	52	28.5
Lower back	84	46.1
Wrist	24	13.1
Forearm	14	7.6
Knees	29	15.9

(28.5%). As shown in Table 3, BMI of insurance office employees with top four body regions with most prevalent symptoms are discussed in groups as underweight (>18), normal (18–25), overweight (26–30) and obese (>30).

In Table 4, Frequency of Rest break once in more than 4 h was strongly associated with all MSD's in all body regions. The travelling hours of more than 3 h/day related to work is also associated with upper back pain and low back pain.

Table 3 BMI of employees participated with top four body regions with the symptoms

Body regions	BMI (kg/m^2)				p	x^2
	>18	18–25	26–30	>30		
Neck	2 (1.1)	35 (18.7)	61 (33)	8 (4.4)	0.73	1.294
Lower back	2 (1.1)	22 (12.1)	46 (25.3)	14 (7.7)	**0.037**	**8.457**
Shoulder	2 (1.1)	24 (13.2)	36 (19.8)	8 (4.4)	0.534	2.191
Upper back	1 (0.5)	16 (8.8)	30 (16.5)	5 (3.3)	0.81	0.963

P values less than 0.05 are taken significant, the corresponding confidence level is 95%

Occupational physical risk factor—rest break frequency produced the highest OR for the neck and upper back symptoms (OR = 6.69, 95%CI 2.06–21.65), followed by low back and then shoulder. The daily travelling hours was a significant factor associated with upper back symptoms and lower back. The rest break frequency demonstrated to be the most significant factor associated with the symptom scores for all four body areas.

4 Discussion

The current study shows the significant and strong association of BMI with low back pain. This may be due to occupational work load which leads to prolonged sitting that reduces the physical movement of the body. The frequency of rest break of once in more than 4 h is the most contributing factor which affects the MSD significantly in all the four major body regions-neck, upper back, shoulder, and lower back. This attributes to the prolonged sitting which affects all these body regions. The travelling h/day for the work is also significantly associated with lower back and upper back pain. The back region is affected by daily travelling of more than 3 h.

In our present study, the observed 12-month prevalence of neck pain was slightly higher to that reported in New Zealand office workers (51%) [10] and somewhat higher than among a sample of UK office workers (38%) [18]. The prevalence of low back and shoulder pain during the past 12 months was close to that in the other two countries. As in several other studies of office workers [3–5, 12], the neck was the most common site of pain.

The main factor contributing to MSD among staff is probably the frequency of rest breaks of only once in >4 h which is very less in daily work. So, prolonged sitting in office environment is the leading cause of MSD.

Table 4 Statistical association of occupational risk factors with self reported musculoskeletal disorders

Occupational risk factors	Neck			Low back			Shoulder			Upper back		
	p	OR	CI	*p*	OR	CI	*p*	OR	CI	*p*	OR	CI
Working h/day												
7–8	0.446	1.5	0.52–4.33	0.359	1.63	0.57–4.63	0.783	1.15	0.42–3.13	0.273	1.82	0.62–5.32
>8 h	0.335	0.25	0.01–4.16	0.225	0.99	0.07–3.93	0.778	0.69	0.05–8.57	0.453	0.83	0.25–5.54
Rest break frequency												
Once in <2 h	0.179	2.15	0.70–6.61	0.78	1.17	0.37–3.65	0.147	0.41	0.12–1.36	0.369	1.8	0.49–6.50
Once in 2–4	0.253	3.1	0.85–9.04	0.32	2.25	0.46–4.83	0.434	0.85	0.15–2.84	0.263	1.26	0.25–4.26
Once in >4 h	**0.002**	6.69	2.06–21.65	**0.001**	6.45	2.06–20.23	**0.046**	1.36	0.49–3.74	**0.002**	6.69	2.06–21.65
Travelling hours												
>1	0.134	2.41	0.76–7.66	0.899	0.92	0.29–2.95	0.85	1.11	0.36–3.35	0.267	0.5	1.48–1.69
1–3	0.103	3.55	0.77–16.32	0.476	1.68	0.40–6.98	0.425	1.75	0.44–6.96	0.301	0.41	0.01–2.20
>3	0.445	2.79	0.20–39.04	**0.032**	1.74	0.04–9.52	0.252	4.48	0.34–58.39	**0.045**	1.69	0.54–32.32

P values less than 0.05 are taken significant, the corresponding confidence level is 95%

5 Conclusion

In conclusion, body mass index was found to be significantly associated with the symptoms and severity of the lower back region. Frequency of rest break once in more than 4 h was strongly associated with all MSD's in all body regions. The travelling hours of more than 3 h/day related to work is also associated with upper back pain and low back pain. The perception of faulty workplace design and layout is also strongly associated with musculoskeletal symptoms.

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Chapter 6
Assessment of Forearm Muscle Work in Various Dental Activities

Tejashree A. Dabholkar, Sujata Yardi and Ajit Dabholkar

Abstract Conservative Dentistry has the primary goal of the diagnosis and treatment of dental caries and includes the techniques and procedures to restore the teeth to full function and appearance. There is paucity of literature available about the type of muscle work in dental procedure. Since dentists need good manual dexterity as well as hand skills, studying the muscle activity in the forearm during dexterity tasks would give us an idea about type of muscle work involve. Hence this study aims at doing electromyography analysis of the same. In this study design, postgraduate students and dental faculty of Conservative dentistry department were evaluated for muscle work of flexor carpi ulnaris (FCU), extensor carpi radialis longus (ECRL), flexor digitorum profundus (FDP), and flexor digitorum superficialis (FDS). These muscle works were assessed while performing common dental procedures like drilling, pulp excavation, and filling. Surface electromyography was used for the study. Study suggests that FCU has no difference of muscle work (Friedmans test $P = 0.16$) for all three dental procedures. ECRL ($P = 0.029$) has more muscle work while performing fine activity as pulp excavation whereas for muscles like FDP and FDS muscle work increases in fine activities like filling and pulp excavation. Difference of muscle work among various dental activities for FDS and FDP is $P = 0.001$ and $P = 0.0095$ respectively. This study demonstrates that the risk associated with repetitive dental tasks should be considered as weight and design of instruments could be having influence on muscle work.

Keywords Forearm · Muscle work · Dental activities · Electromyography

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1 Introduction

Conservative Dentistry has the primary goal of the diagnosis and treatment of dental caries and includes the techniques and procedures to restore the teeth to full function and appearance. The treatment provided includes various fillings, root canal treatment. Surgical endodontic, endodontic implants, bleaching and management of traumatized teeth which are most of the commonest procedures. Occupational reasons leading to musculoskeletal disorders (MSDs) include repetitive bending movements of wrist, to catch devices forcefully with ulnar deviation and repetitive pressure on palm. In dentistry practices, these movements (especially repetitive movements of wrist) are used during exfoliation and canal cleaning that can compress median nerve [1]. Since dentists need good manual dexterity as well as hand skills, studying the muscle activity in the forearm during dexterity tasks would give us an idea about type of muscle work involve. Scaling and root planning pose a high ergonomic risk for both, dentists and dental hygienists. A small cohort study [2] measured muscle activity of the flexor carpi radialis, brachioradialis, and extensor carpi radialis with surface electromyography during the daily work of dental hygienists and found that the average muscle activity during dental scaling was 15–18% of the maximum voluntary contraction. Study done by Dong et al. [3], to check the effect of finger rest position on forearm muscle work has found that using finger rest is responsible for reduced muscle work load on hand muscles.

Thus the objective of this study is to determine the amount of work happening in the forearm musculature during the various activities like drilling, filling, etc. performed by the dentists, using electromyography studies.

2 Methodology

Nineteen subjects were recruited from among postgraduate student volunteers and staff at Dr. D.Y. Patil dental college, Department of Conservative dentistry. The average age of the subjects was 28.47 $\pm$ 1.77 and the mean of the work experience, i.e., no. of practicing years was 4.91 $\pm$ 1.82. There were 10 (51%) males and 9 (49%) females who participated in the study. This sample size is based on previous studies of intensive hand tasks in which EMG measures were a primary outcome. The sample size necessary for three conditions with a power of 90 and 95% confidence is 12 subjects. The protocol for the study was reviewed and approved by the Institutional ethics Committee of Dr. D.Y. Patil University. Informed consent was obtained from all participants before the study. Subjects were asked to fill up their personal details like name, age, gender, work experience, and work details.

2.1 Electromyography

Surface electromyography (EMG) is a frequently used tool for measuring muscle activity while performing various workplace tasks. The signal from surface EMG is affected by several factors, which include tissue filtering, electrode location, inter-electrode distance, and activity of nearby muscles. Surface bipolar electromyography (EMG) recordings were used to measure muscle activity during the dental tasks. EMG signals were obtained using circular Ag/AgCl electrodes with an active diameter of 8 mm and a center-to-center distance of 21 mm. The EMG signals were amplified with preamplifiers and an adjustable-gain amplifier. The amplifier produced the root mean square (RMS) of the EMG signal. Sites on the right forearm for the placement of the electrodes were localized using recommended anatomical placement [4]. Two extrinsic hand muscles that experience high loads during a sustained pinch were studied: the flexor digitorum superficialis (FDS), the flexor pollicis longus (FPL). Two wrist muscles like extensor carpi radialis longus (ECRL) and flexor carpi ulnaris (FCU) were also studied. A ground electrode was placed over the lateral epicondyle. The skin was shaved (if necessary), abraded and cleaned with an alcohol pad prior to placement of the electrodes. Prior to performing the dental procedures, maximum voluntary contractions (MVCs) of the four muscles were recorded in two postures: (1) the typical pinch and wrist posture used during root planning, and (2) a wrist extension posture with all fingers, except the thumb, performing a maximum resisted finger extension. Subjects performed the contraction for 3–5 s and repeated each MVC manoeuvre three times. The MVCs for the muscles FDS and FPL were calculated from the EMG signals recorded in the pinch posture, while the MVCs for ECRL was calculated from the wrist extension posture. MVC for FCU was calculated with wrist in flexion and ulnar deviation. The MVC was selected as the highest value of a 1-s moving average of the RMS EMG signal across a trial. The average of three trials was used to represent the MVC of each muscle. Subsequently obtained EMG signals were normalized as a percentage of the MVCs.

Dentists were asked to continue with their work of treating the patient. EMG readings were taken while they treated the patient. Two main procedures were taken into consideration, which were root canal treatment and filling which were the commonly performed procedures of the Conservative Dentistry Dept. EMG readings were taken when the subjects performed the sub-activities like drilling and pulp excavation (these are the sub-activities of root canal treatment) and composite filling (this formed a sub-activity of filling) using respective instruments. For each task, a representative 5-s window of data was used to calculate values of the EMG RMS signals for each muscle.

3 Result

See Table 1.

4 Discussion

The purpose of this study was to assess the forearm muscle work and check the pattern in various dental procedures. This study suggests that for muscle like FCU which has to constantly work in order to stabilize the wrist has no significant difference of activity. For smaller to larger activities muscle has to constantly work. ECRL has significant difference of muscle activity between drilling and pulp excavation (Table 1). Drilling activity needs the tool to be held strongly for which muscle work increases. In all the three activities the dentists used a precision grip for holding the instruments. This requires proper stabilization of the wrist which is brought about by the extensors and the flexors of the forearm, thus it places more demand on the ECRL/B as well as the FCU muscle. Also the movements of the wrist performed by the subjects consisted mainly of wrist extension (which remained static) along with repetitive ulnar and radial deviation which indicates that there is a specific arc of movement that is followed by the wrist which demands stability along with mobility and is achieved by the ECRL. It acts not only as a prime mover but also as a stabilizer at the wrist [5]. The activity of ECRL is more as compared to FCU. Furthermore a dental drill also called as air rotor (rotates at a speed of approximately 400,000 rpm) is a small, high-speed drill used during dental procedures, usually to remove decay and shape tooth structure prior to the insertion of a filling or crown. While drilling, continuous vibration is felt in the fingers and along with the vibrations working in a specific dimension can impose more work on the forearm muscles for stabilization which can explain the maximum activity of the muscles in drilling. Pulp Excavation is another sub-activity of root canal treatment in which a bur is used. Pulp excavation is careful excavation of caries at the base of the cavity overlying the pulp until a hard dentine is reached; this is checked using a bur. It involves putting the bur into the cavity and rolling it over with the fingers.

Table 1 Results of comparison of forearm muscle work with various dental activities

	RMANOVA	D versus PE	D versus F	PE versus F
FDS	$P = 0.001$***	$P < 0.001$***	$P < 0.01$**	$P > 0.05^{\#}$
FPL	$P = 0.0095$**	$P < 0.05$*	$P < 0.05$*	$P > 0.05^{\#}$
ECRL	$P = 0.0295$*	$P < 0.05$*	$P > 0.05^{\#}$	$P > 0.05^{\#}$
FCU	$P = 0.16^{\#}$	–	–	–

The second column is the repeated measures ANOVA, except for flexor carpi ulnaris (Friedmans test). Columns 3, 4, and 5 present the pairwise comparisons using the Tukey method
***Extremely significant, **very significant, *significant, #not significant
D drilling, *PE* pulp excavation, *F* filling

Thus even though pulp excavation needs stabilization it does not need much of wrist movements which could be the reason that the muscle work of the FDS and FPL is significant in this activity. Filling is another activity which is performed most frequently in the Conservative Dentistry department. Study done by Dong et al. [6] have suggested effect of tool design and weight on hand muscle load, study shows that with larger diameter and light weight tools least amount of pinch force and muscle load is required. Our study also suggests least muscle activity of FPL and FDS in drilling as compared to filling and pulp excavation.

In a study done by Kierklo et al. [7] to find out the Work-Related Musculoskeletal Disorders Among Dentists—A Questionnaire Survey on 220 polish dentists, it was found that around 15–16% of the respondents presented with pain in the elbow due to improper working habits and deficiency of basic knowledge of ergonomics. Thus it would be ideal to make the dentists aware of the proper ergonomics and also design instruments or splints which would help them relieve the load off the forearm muscles. Study done by Pitts [8] suggests that lot of dentists experience pain and discomfort in the area of elbow forearm and wrist ergonomic consideration of this area is needed.

5 Conclusion

Repetitive dental tasks can increase muscle work. Small extrinsic muscles of hand like FDP and FDS show excessive muscle work while performing fine dental procedures. Wrist stabilizers like ECRL and FCU shows increased muscle activity.

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Chapter 7
Investigation of Magnitude of Musculoskeletal Disorders Among Cotton Spinning Operators

Dhananjay Ikhar and Vishwas Deshpande

Abstract Cotton spinning on charkha is observed to be an important operation in small-scale cottage textile industries in India. The majority of women workers in these industries performs cotton spinning task adopting an uncomfortable posture. A survey was conducted to assess the effect of bad postures on the operator. A Dutch Musculoskeletal Questionnaire (DMQ) was used to evaluate 40 operators regarding work-related musculoskeletal disorders (WMSDs). DMQ was categorized in background variables, physical complaints attributed, repetitiveness and exertion associated with work and force exertion. After statistical analysis using SPSS, it was observed that 50% operators were suffering from musculoskeletal pains in different body regions due to working conditions and ergonomic environment. Musculoskeletal loads have also evaluated with the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) techniques. It is revealed that the health of spinning operators was highly affected due to improper body postures and workload. Twisting, bending and over reaching were the resultant of poorly designed workstations. These postures force them to work in a non-neutral position that increases the overall discomfort and pain in the lower back, neck and shoulder. An exponential model is developed based on response data from DMQ and also validated using ANN Simulation.

Keywords DMQ · Ergonomics evaluation · Musculoskeletal disorders · RULA · REBA

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Fig. 1 Working posture adapted in order to perform spinning operation

1 Introduction

Stooped and squatting postures are common in developing countries such as India especially in small-scale industries [1, 2]. Most of the manually energized operations in these industries are carried out in uncomfortable postures. A hand-operated cotton spinning workstation was identified where operators are mostly women. Cotton spinning wheel, more commonly known as "charkha", is a hand-powered device for spinning cotton yarn from pressure clamp. The spinning operation is performed in a squatting position where operator rotates spinning wheel sitting down on the hard and flat surface with folded knees without any backrest. Figure 1 shows the details of posture adapted. The task of rotating the wheel for cotton spinning is repetitive and continuous for 8 h of working in a day.

The objective of present study is to analyze the working postures and conduct ergonomic evaluation of the workstation to identify need of intervention with Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) and to investigate the magnitude of musculoskeletal disorders among charkha operators using Dutch Musculoskeletal Questionnaire (DMQ).

2 Materials and Methods

A cross-sectional observational type study was conducted in spinning section of small-scale labour-intensive workshops by name "Gram Seva Mandal" and "Mahatma Gandhi Institute of Rural Industrialization (MGIRI)" in city Wardha, Maharashtra state, India. The study was carried out after obtaining the informed consent of the operators in both the workshop. Management has supported and committed to implementing any recommendations based upon the results to ensure high response rate. The reasons for the study as well as its goals and contents were communicated clearly to all involved subjects along with how results will be useful for their health improvement. From both workshops, 40 women operators in the age ranging from 18 to 60 years were selected. All those who consented voluntarily were included in this study. A field survey has been conducted to formulate the research problem. RULA and REBA techniques were used to assess the posture, force and movement of the neck, upper and lower back, trunk, shoulders associated with cotton spinning task and to measure the body posture, forces used, type of movement or action, repetition and coupling, respectively. Dutch Musculoskeletal Questionnaire [3] was used to measure the magnitude of musculoskeletal disorders among cotton spinning operators. The statistical analysis of response data has been analyzed using SPSS software. A mathematical model has been formulated using MATLAB for dependent output parameters, i.e. various MSDs in neck, upper back, lower back, shoulders, elbow, knee, wrist/hands, hip and ankle/feet. The influence of the model indices has been measured using sensitivity analysis technique. ANN simulation was conducted for the reinforcement of reliability of the model.

3 Results

3.1 Field Survey

The existing workstation has been studied. All operators were women operators and used to carry out their work in a continuous manner for 8–10 h per day with a rest pause of 15–30 min. Plant layout provides insufficient gaps between the workstations which causes inadequate space for relaxing legs while operating the device. Improper ventilation and lack of illumination intensity (325 lx) provide the poor working environment. Operators have to handle two types of spinning machines.

3.2 Socio-demographic Characteristics of Study Subjects

Total of 40 female subjects were studied. The mean age was 38.5 years; mean height was 151 cm and mean weight being 50.8 kg. The mean work experience was 8 years. On an average, they worked for 8 h every day (Table 1).

Table 1 Socio-demographic characteristics of study subjects

Variable	Mean	SD	Range
Age (years)	38.5	8.96	18–60
Height (cm)	151	11.45	145–165
Weight (kg)	50.8	8.9	45–60
Work experience (years)	8	4.69	1–18
Weekly working hours	48	1.35	45–50

Table 2 Final scores of RULA

Tasks	Grand score	Action level
Task 1: Rotating input wheel	7	4
Task 2: Rejoining of broken thread	5	3

3.3 RULA Analysis

Rapid Upper Limb Assessment (RULA) is a survey method developed for use in ergonomic investigations of workplaces where work-related upper limb disorders are reported. [4]. The final grand score for the task 1 was 7 which indicates an action level 4 attention, i.e. immediate investigation and changes are required in existing workstation. For task 2, the grand score was found to be 5 which indicate an action level 3, i.e. prompt investigation and changes are required in existing workstation (Table 2).

3.4 REBA Analysis

REBA was developed to produce a new tool incorporating dynamic and static postural loading factors, human-load interface (coupling) and a new concept of gravity assisted upper limb position [5]. The final REBA score is found to be 11 which suggests that the risk level is very high and implies that the working posture is not correct ergonomically and modification is required immediately.

3.5 DMQ Analysis

A Dutch Musculoskeletal Questionnaire (DMQ) was used for the assessment of work for measuring physical discomfort. It is a standardized method relatively inexpensive and easy. There is no need of any technical equipment to conduct this survey. Responses were collected from the workers and statistical analysis was carried out using SPSS software. Some of the significant results are discussed in this paper.

3.5.1 Perceived Pain Status

Table 3 shows the related results in the percentage of worker experienced pain in a different region of the body in this occupation. The majority of the study subjects, i.e. 80% have experienced pain in right shoulder whereas left shoulder pain was experienced by 70%. Right wrist/hands and right knees (both 72.5%) were the second most painful sites observed in the study population.

Table 3 Physical complaints attributed to work by the study subjects

Variable	% pain experienced		
		Freq.	Percentage
Neck		21	52.5
Upper back		26	65
Lower back		26	65
Shoulders	Left	28	70
	Right	32	80
Elbows	Left	17	42.5
	Right	17	42.5
Wrist/Hands	Left	23	57.5
	Right	29	72.5
Hips/Thighs	Left	20	50
	Right	20	50
Knees	Left	23	57.5
	Right	29	72.5
Ankles/Feet	Left	15	37.5
	Right	15	37.5

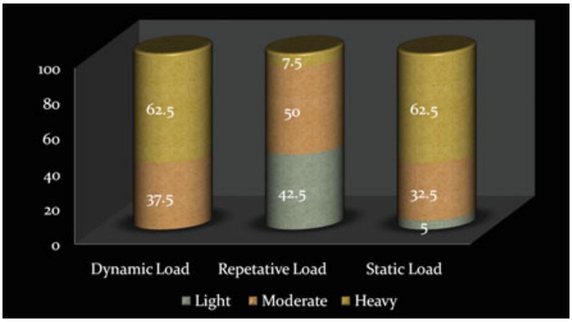

Fig. 2 Perceived workload

3.5.2 Perceived Workload and Ergonomic Environment

Figure 2 shows that the majority of the workers (62.5%) perceived the dynamic load as heavy, half of the workers perceived the repetitive load as moderate while 62.5% workers perceived static load as heavy. The majority of them, i.e. 57.5% perceived the ergonomic environment as poor.

4 Formulation of Model

From the outcomes of statistical analysis, it is revealed to develop a mathematical model for the data collected through DMQ questionnaire. The data of the independent and dependent variables of the system has been gathered during experimentation. In this case, there are nine dependent and 28 independent variables. It is necessary to correlate quantitatively these independent and dependent variables involved in the experimentation.

5 Discussion

The results of this study revealed that the cotton spinning operators are engaged in prolonged forward bending posture in their working condition. The study showed that 50.62% of an average value of the subjects suffering from at least one work-related musculoskeletal pain. The study carried out by Montreuils et al. on textile tufting workers handling thread cone has reported that 64.9% workers had at least one work-related musculoskeletal pain among various sites in body regions [6]. Research outcome of a study conducted by Punnett et al. related to female garment workers indicates that the majority of participating subjects in the study are experiencing shoulder, back and wrist pain because of repetitive nature of the operation and a poor design of spinning wheel [7]. Similar findings had been reported by [8, 9]. Grandjean has reported the disadvantage of sitting posture which causes a disturbance in digestion and breathing. A prolonged slacking of the abdominal musculature and the purported ill effect of the flexion of the lumbar spine also contribute to this [10]. In addition to the percentage of musculoskeletal complaints, this study also reflected the working posture analysis using RULA and REBA. Identical research works conducted by Ghosh et al. signify findings related to musculoskeletal pains due to awkward posture adapted by the goldsmiths in India [11].

Results obtained through mathematical modelling of the responses collected through DMQ questionnaire are found to be significant. The model selected was an exponential model which is used to study the influences from the indices obtained through the model for all 9 dependent parameters, i.e. neck, shoulders, upper back, lower back, elbow, wrist/hands, hip and ankle/feet. The sensitivity analysis for the exponential model was studied thoroughly. Influence of independent parameter over dependent was interpreted.

For cotton spinning occupation, it has been observed that age is having an influence on a prevalence of MSDs in the body regions like lower back (5.05%), elbow (6.78%), knee (4.01%), hip (4.16%) and ankle/feet (8.00%). Duration of occupation has a greater impact over MSDs in hip region (5.13%) compared to MSDs in other body regions. Health status, in general, is found to be influent on neck (15.75%), hip (16.04%), wrist/hand (12.47%) and ankles/feet (12.35%). As reported in the questionnaire, past working in squatting and kneeling posture was also observed. The analysis shows more impact of past working posture on hip (8.79%) and ankle/feet (4.97%). It has been reported that present work is also carried out under shoulder level and in an uncomfortable posture. It has significant influence over a generation of MSDs in elbow (24.85%), neck (15.17%) and upper back (13.71%). Over 80% of cotton spinning operators is having upper back pain since last 12 months in this occupation. Twist and bend in neck or posture also contributed to the developing of upper back pain. Sudden and repetitive movements (1.306), the stress developed in neck and shoulder (1.161), radiating pain from neck and shoulder were found to be very significant in the prevalence of MSDs in the elbow. The overall weight of the body and dynamic loads led to the development of pain in the knee, for which 12% of operators had visited the hospital.

6 Conclusion

This research has proved that the health of the operators is significantly affected and there exists a very high degree of risk that these operators would develop MSDs in various regions of the body. Obtained results indicate the areas of improvement in the posture of spinning operators and the workstation design. The majority of the subjects in this study had shoulder, back and wrist pain due to repetitive nature of the job and the poor design of spinning workstation. MSDs are prominent in this study as the female subjects adopt prolonged sitting posture without any backrest and remain in this position for at least 8 h a day. As there are residual pain and fatigue, the productivity slows down. The RULA (7) and REBA (11) score indicate that the posture is poor and needs urgent attention for modification. Dynamic and repetitive loads experienced by the operator are found to be significant which lead to the prevalence of MSDs in the operators. DMQ also indicates the statistics regarding pain in various regions of the body of the operator. MSDs in neck, upper back and lower back seem to be prominent in the cotton spinning occupation due to heavy dynamic load. Sudden repetitive movements and BMI are also contributing to the generation of MSDs in almost all 9 response variables. Pains in lower back, neck, upper back and hips are majorly influenced by BMI and duration of the occupation. Perceived influences indicate the urgent need of redesigning the cotton spinning workstation to reduce the prevalence of MSDs in this occupation.

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Chapter 8
Working Period, Year of Exposure and the Prevalence of Musculoskeletal Disorders Among the Saw Mill Workers: A Cross-Sectional Study

Asit Adhikari and Subhashis Sahu

Abstract The major portion of the work forces belong to unorganized sector and sawmill is one of those. The present study aimed at finding the relation of musculoskeletal disorders of saw mill workers and their exposure experience. Seventy eight workers were randomly taken and they were classified into three different groups on the basis of years of exposure (≤ 5; 5–10 and >10 years): and other classification is based on working hour, i.e. Exposure-1 (8 h/day) group and Exposure-2 (10 h/day) group. Modified Nordic musculoskeletal disorders (MSDs) questionnaire and Oswestry low back disability questionnaires were applied. Rapid entire body assessment (REBA) posture analysis technique was done for analysis of their working posture. The discomfort feeling at different body parts (especially neck, shoulder, upper back, wrist/hand, knee and ankle) is significantly (*P* value is considered as 0.05) higher in third group (>10 years experienced) of workers than that of other two groups. Discomfort feelings at different body segments (upper back, wrist/hand, hip, knee ankle and elbow) in Exposure-1 group are significantly ($P \leq 0.05$) high compared to Exposure-2 group workers. REBA posture analysis technique shows more than 60% working postures are above high risk level. Third group (>10 years experienced) is higher in MSD problems than other two groups (5–10 and ≤ 5 years experienced).

Keywords MSD · Sawmill · REBA · Working period and year of exposure

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1 Introduction

A large number of people are involved in wood processing industry for their live hood. Indian economy is characterized by the existence of high level of informal or unorganized labour employment. The workers from organized sectors comprise only 7% of the total workforce of the India while the rest 93% belongs to the unorganized sectors [23]. But unfortunately there is no such statistical data on Indian perspective that could be highlight the total number of people who are working in the saw mill industries.

The major activities performed by the saw mill work forces are sawing the logs, resawing, carrying the logs, replacement of cutting timbers from the trolley, pulling the chain, pushing the trolley, transferring the awed logs, moulding the saw blade and removing the wood dust [4]. The workers in saw mills are exposed to musculoskeletal disorders (MSD) risks due to many risk factors [3, 5, 8–11, 13, 15, 17, 18, 22, 24], hard environmental conditions (high temperatures, slippery and uneven ground), heavy works (manual handling of loads, awkward postures) and dangerous tools and machineries such as chainsaws, band saw, chippers, etc. also. [1, 21].

Sawmill spreads almost all parts of India and large number of people are engaged in this industry for their daily live hood. But there are no such data which can highlight the workers' health in relation to the working period and working experience on Indian perspective. So, the present study is the effect of working period and working experience (in years) on the prevalence of musculoskeletal disorders of the sawmill workers.

2 Methods

2.1 Study Population

A total of 78 male persons were randomly selected from different districts of West Bengal for the present study. They are classified into two types of sub-groups; one type of classification is ≤ 5 years ($N = 20$), 5–10 years ($N = 16$) and >10 years ($N = 42$), on the basis of working experience and another type is Exposure-1 ($N = 45$) and Exposure-2 (33), on the basis of working hours per day. Subjects were excluded from this study those were suffering previous history of any chronic illness, injury or any surgical operation. The subjects were earlier informed about the study.

2.2 Measurement of Physical Parameters

Height and weight of each subject was measured by using standard Martin anthropometric rods and digital weighing machine, respectively. From the above readings, body mass index (BMI) and body surface area (BSA) of individual subjects were calculated [2, 25], respectively.

2.3 Questionnaire Study

The Modified Nordic Questionnaire [16] and Oswestry low back pain disability questionnaire [7] were administered in local language (Bengali) and then it is translated in English to validate the questionnaires.

2.4 Analysis of Working Posture

The analysis of different working posture of saw mill workers was done by using technique Rapid Upper Limb Assessment (REBA) [12]. The postures of different activities were recorded by digital photography and later on, stick diagrams were made. The most frequent postures adapted by the workers were considered for the study.

2.5 Statistical Analysis

To find out the significant different of discomfort feeling in different body parts of the comparison groups (between Experienced groups; Exposure-1 and Exposure-2), Chi-square test was done and Student's t test was performed to find out whether there was any significant difference between the Exposure-1 and Exposure-2. ANOVA was done for finding out the association between work experienced groups.

3 Result and Discussion

Analysis of working postures, workers most adopted were depicted in Table 1 and the stick diagrams of those particular postures were also drawn. To analyse the activities and the working posture of sawmill workers, rapid entire body assessment (REBA) method has been used.

Table 1 Analysis of different working postures

Sl. No.	Posture	Stick diagram	Activities	REBA score	Risk level	Action to be taken
1			Pulling the wooden log for carry out	12	Very high risk	Investigate and implement change
2			Pushing the trolley for restart	11	Very high risk	Investigate and implement change
3			Replacing the cutting timber	12	Very high risk	Investigate and implement change
4			Processing the log	8	High risk	Investigate and implement change
5			Pushing the log for carry	10	High risk	Investigate and implement change
6			Pulling the log with the help of rope	11	Very high risk	Investigate and implement change

Awkward working postures cause harm full effect on the health or may lead the development of musculoskeletal disorder [14, 20]. So, the present study shows that the saw mill workers are in high risk level and that is why work-related musculoskeletal disorder (WRMSD) developed and they claimed for pain in their different body parts.

Beside this the saw mill workers always do work in standing and stooping posture for a long time without any break this may another reason of their WRMSD. Another thing is during their activities, they always do movement their wrists and hands that may cause their shoulder, neck and wrist pain more [4, 6, 19].

Table 2 is clearly indicating that there are no any significance difference of physical parameters within comparisons sawmills workers.

After analysis of Modified Nordic Questionnaire, almost all subject said they are feeling discomfort in their daily life.

Table 3 clearly shows that Exposure-2 personnel feeling more discomfort than the Exposure-1 personnel, i.e. more time spent in the job in a working day more will be the chance of discomfort feelings of different body parts of saw mill workers.

From the analysis of response of Oswestry low back questionnaire, it is clear that the workers engaged in more time in the work in a day are in more trouble for low back pain/and leg pain which in turn affects their daily life than less time engaged saw mill workers (Fig. 1).

Table 2 Comparison of physical parameters between Exposure-1 and Exposure-2 groups

Parameters	Exposure-1 (N = 45)	Exposure-2 (N = 33)	t test	P value
Age (years)	41.06 ± 8.19	41.27 ± 8.44	0.110	0.912 (NS)
Height (cm)	162.03 ± 5.24	161.03 ± 3.92	0.923	0.359 (NS)
Weight (kg)	56.69 ± 8.12	56.24 ± 6.26	0.266	0.791 (NS)
BMI (kg/m^2)	21.55 ± 2.68	21.57 ± 2.28	0.035	0.973 (NS)
BSA (m^2)	1.60 ± 0.13	1.58 ± 0.09	0.7517	0.455 (NS)

NS non-significant
Data are presented as mean and SD

Table 3 Showing the comparison of discomfort feeling/pain sensation of the different body parts between two groups of sawmill workers

Body parts	Exposure-1 (N = 45)	Exposure-2 (N = 33)	Chi-square	P value ($P \leq 0.05$)
Neck	29	26	1.26	0.261 (NS)
Shoulder	30	27	1.52	0.217 (NS)
Upper back	16	21	4.95	0.026 (S)
Lower back	35	29	0.72	0.396 (NS)
Wrist/hand	23	25	3.9	0.048 (S)
Hip	8	14	4.56	0.032 (S)
Knee	8	16	7.05	0.008 (S)
Ankle	11	17	4.94	0.026 (S)
Elbow	7	15	6.99	0.008 (S)

NS non-significant, *S* significant
Subject's positive responses were accounts to consider

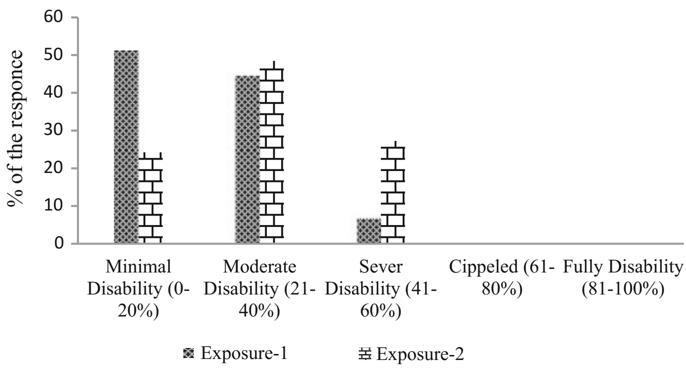

Fig. 1 Comparison of percentage of low back pain of Exposure-1 and Exposure-2 saw mill workers groups

Table 4 Comparison of physical parameters among three groups of saw mill workers

Parameters	≤5 years (N = 20)	6–10 years (N = 16)	>10 years (N = 42)	F value	P value
Age (years)	38.4 ± 9.36	40.06 ± 7.16	43.11 ± 7.49	2.617	0.080 (NS)
Height (cm)	163.18 ± 5.12	161.28 ± 2.79	160.99 ± 5.03	1.525	0.224 (NS)
Weight (kg)	57.88 ± 7.70	55.33 ± 6.26	56.21 ± 7.63	0.518	0.598 (NS)
BMI (kg/m^2)	21.64 ± 2.31	21.32 ± 2.21	21.61 ± 2.73	0.091	0.913 (NS)
BSA (m^2)	1.61 ± 0.12	1.59 ± 0.11	1.58 ± 0.12	0.432	0.65 (NS)

NS non-significant
Data are presented as mean and SD

Table 5 Showing the comparison of discomfort feeling/pain sensation of the different body parts among three groups of sawmill workers

Body parts	≤5 years (N = 20)	5–10 years (N = 16)	≥10 years (N = 42)	Chi-square	P value ($P \leq 0.05$)
Neck	10	10	34	6.52	0.038 (S)
Shoulder	11	10	36	7.64	0.021 (S)
Upper back	5	6	26	8.2	0.016 (S)
Lower back	16	13	39	2.64	0.26 (NS)
Wrist/hand	8	9	31	6.78	0.033 (S)
Hip	5	6	11	0.87	0.647 (NS)
Knee	3	3	18	6.3	0.04 (S)
Ankle	3	4	19	6.2	0.045 (S)
Elbow	3	2	17	6.79	0.033 (S)

NS non-significant, *S* significant
Subject's positive responses were accounts to consider

The subjects' physical parameters are compared among three groups of workers which are presented in Table 4.

Table 5 is indicating more the working experience more will be the chance of discomfort feelings of different body parts (except lower back and hip) of saw mill workers.

More the working experience more will be the chance of discomfort feelings of different body parts of saw mill workers.

Figure 2 clearly shows that second and third group of workers are affecting their daily life activities more than first group of workers, i.e. more working experience may develop more the risk of getting low back/and leg problems that in turn affects the daily life of saw mill workers.

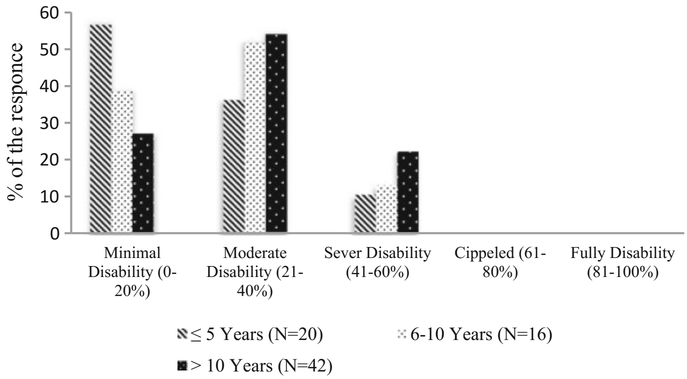

Fig. 2 Comparison of percentage of low back pain of three different experienced saw mill workers groups

4 Conclusion

From the present study it can be concluded that the saw mill workers are always suffering different kinds of work related musculoskeletal disorders (WRMSDs). They are working in different awkward postures day to day, which leads to increase in their WRMSDs and above 60% of the total working postures are in above high risk level. Discomfort feelings or pain sensation in different body parts of the saw mill workers are increase with lengthening of daily working period, (i.e. hours in a day) and working experience, (i.e. year of exposure). The discomfort feelings of the work force in turn affect their daily life and as the working period or/and working experience increases the result goes adverse. Lastly, hands/wrists lose its strength with increasing of working period and working experience.

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Chapter 9
Duration of Exposure (Working Hours) and Musculoskeletal Discomfort/Pain

Urmi R. Salve and Amitabha De

Abstract Indian traditional jewellery manufacturing plays an important role in the national economy. There are several studies which discuss about various hazards especially chemicals, among jewellery manufacturing workers in India. But studies related to evaluation of musculoskeletal disorders and its causal effect have not been evaluated in any of such studies. This study has been carried out to identify one of the causal factor (duration of exposure) of the development of work-related Musculoskeletal Disorders (WRMSD) and its association with prevalence rate. Prevalence of musculoskeletal disorders was recorded using Nordic Musculoskeletal Discomfort Questionnaire (NMQ). Data related to duration of exposure to jewellery manufacturing were collected using diary method and direct observation. Statistical analysis of the data revelled that there was a significant correlation between duration of exposure and the prevalence of low-back pain. Whereas the correlation was absent with knee and neck pain.

Keywords WRMSD · NMQ · Low-back pain · Using diary method · MSD

1 Introduction

Traditional Indian gold jewellery manufacturing is unique in nature. It implies in national economy as well as it has a cultural value. The whole process is separated in various steps, such as designing, casting, model making, setting (metal and stone), finishing and polishing. Each step is performed under crucial inspection (quality control).

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There have been many studies carried out to identify various hazards especially chemical hazards among the gold jewellery manufacturing in India. But less study have been reported which discuss the postural and working hour issues for development of work-related musculoskeletal disorders. The Indian traditional jewellery manufacturing required seated working posture. The workers work in a squat position on the floor keeping their trunk in forward bending with twisted neck. This posture increases the postural risk to develop various WRMSD. Therefore, there is a possibility of increased interdiscal pressure and increased load on back muscles that stabilize the work posture [14, 16]. Work postures sustained over a long period may lead to musculoskeletal disorders [4, 5, 11, 15, 25]. Physiological and epidemiologic studies have demonstrated associations between prolonged sitting and low-back pain. Literature also revealed that there is an association between sedentary work, low-back pain and degenerative changes of the intervertebral discs [9, 29]. Twomey et al. observed that those who sit for half of the time or more on their jobs have about 60–70% increased risk of developing back pain compared to those who sit for less than half the time [28]. Because of static loading of muscles and joints; even natural postures cause aches, pain or other discomforts after an extended period of exposure. Only exposure to the risk factors may not lead to the onset of low-back pain or any other CTD related pain. One of the determining factors is the duration of exposure [1, 2, 6, 12, 22]. The workers engaged in jewellery manufacturing carry out the manufacturing activities for extended period of time. This extended period of work exposure may be the reason for low-back problem. Keeping the above in mind, the effect of work exposure on the development of musculoskeletal disorders among gold jewellery manufacturing workers was studied.

2 Methodology

Study population	Workers engaged in jewellery manufacturing: 385 workers engaged in jewellery manufacturing participated in this part of the study.
Collection of working hours data	The data of working hours per day and working day per week were collected using diary method [31].
Prevalence of MSD	Prevalence of MSD was evaluated using Nordic Musculoskeletal Discomfort Questionnaire (NMQ).

3 Result

Results of 178 subject's responses were included in the study as rest of the subjects did not complete the diary and were not present throughout the observation period. The demographic data of the participants are presented in Table 1.

Working hours per day of workers engaged in the jewellery manufacturing was 14.26 (±1.13) hours. All the workers work for 6 days a week. The workers of the jewellery manufacturing spent their most of the working hours at the desk only.

Annual prevalence of low-back, neck and knee were calculated from NMQ. Statistical analysis (point biserial *r*) was performed using SPSS 16.0. Prevalence rate were presented in Fig. 1.

The above figure revealed that the correlation was present between the prevalence of low-back pain and the working hours per day ($t - 4.197$, $p < 0.001$). The correlation was absent between the working hours per day and the neck ($t - 0.387$, $p > 0.05$) and knee ($t - 0.810$, $p > 0.05$) pain.

Table 1 Demographic data of participants

Parameters mean (±SD)	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Group 1	23.05 ± 4.28	161.55 ± 5.59	54.33 ± 7.54	20.81 ± 2.64

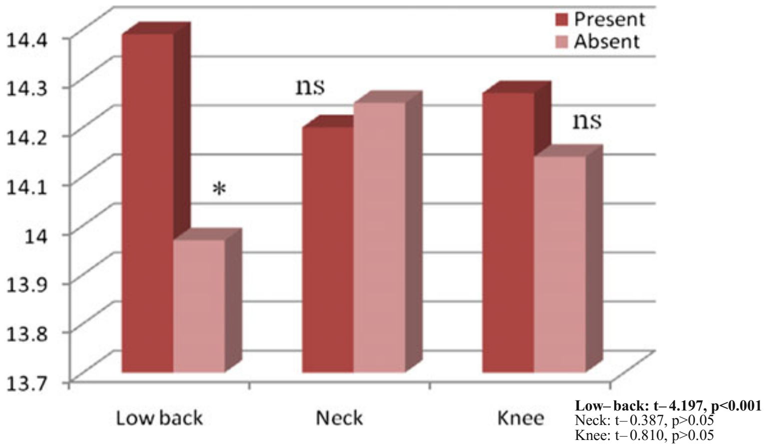

Fig. 1 The relationship between prevalence of musculoskeletal discomforts and working hours ($N - 178$)

4 Discussion and Conclusion

Studies have shown that long working hours has a relation with the presence of different musculoskeletal discomfort [3, 8, 17, 24, 26, 27]. Studies in literature reported that the risk of the development of low-back pain among the sedentary work population is associated with prolonged sitting [10, 19, 20]. Studies also stated that prolonged sitting induce or aggravate the low-back pain [7, 21, 23, 32]. However, some studies contradict the above findings and suggested that there is no association between the prolonged sitting and the development of low-back pain among sedentary working population [13, 18, 30]. Present study revealed that the work duration per day had a positive correlation with the prevalence of low-back pain ($p < 0.001$). In every study in literature, the working posture was very much different from the working posture of the present study. In this study, the jewellery manufacturing workers work in squatting posture on the floor. As it has been established in this study that the work duration has a significant positive correlation with annual prevalence of low-back pain, it is recommended that workers should take various micro-break while working to avoid the development of low-back pain. Further, it is suggested that in other occupations where workers occupy similar posture as in jewellery manufacturing, also need to follow same recommendations.

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Part III
Health and Safety

Chapter 10
Knowledge–Attitude–Practice (KAP) Study and Nutrition Education of Athletic and Non-athletic Teenagers (13–18 Years)

Ashwini R. Sadhu and Deepali Kotwal

Abstract Adequate food is the most important requisite for growth, while it is important throughout childhood, it is more crucial during the early years of life when rapid growth is occurring. It is thus obvious that dietary intake, nutritional status, emotional maturity, and physical fitness are major determinants of physical performance. Pretests were taken to understand the existing knowledge, attitudes and practices' (KAP) prevailing among 300 athlete and 300 non-athlete groups of different schools and sports ground of Nagpur city, Maharashtra, India within age group of 13–18 years. The impact of nutrition education, using power point presentation and booklet, was later verified by post tests and compared. Knowledge of study participants with respect to nutrition show that before training, there was moderate to high level of awareness regarding the nutrition related aspects. After undergoing training, there was a significant ($P < 0.05$) increase with high awareness of the total nutrition knowledge related aspects in majority of the children irrespective of age, gender, and activity. Attitude of subjects toward nutrition shows that before training, majority of non-athletes had moderate level of attitude toward the nutrition related aspects, while majority of athletes had a high attitude toward the same. Comparatively, the total attitude of athletes was noticeably more favorable toward nutrition than the non-athletes. Prior to training, significantly high percentage of children had moderate to high level of practice with respect to nutrition-related aspects. Although there was positive change, the magnitude of the change was lesser than the other aspects of practice as individual needs time to convert his/her knowledge into practice. Thus, delivering continuous education through workshops and courses would help to improve teenagers' nutritional KAP.

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Keywords Nutritional knowledge · Attitude · Practices · Athletes · Non-athletes · Nutrition education

1 Introduction

Nutrition is one of the indispensable factors closely associated with the physical and mental development of young children. Insufficient food will not only result in under-nutrition in terms of inadequate weight gain, but will also hinder growth [8]. Hence nutrition plays a vital role in the development of the quality that helps achieving a high level of public health through a balanced and nutritious diet.

The phenomenal growth that occurs in adolescence, second only to that in the first year of life, creates increased demands for energy and nutrients. Nutrition and physical growth are integrally related; optimal nutrition is a requisite for achieving full growth potential [13]. Failure to consume an adequate diet at this time can result in delayed sexual maturation and can arrest or slow linear growth [13]. Teenagers eating habits are greatly influenced by their rapid growth as well as by self-consciousness and peer pressure. They are under a greater social pressure for thinness, girl may tend to restrict their food and have an inadequate nutrient intake [12]. With increasing longevity and growing concern about diabetes and cardiovascular diseases affecting Indians a decade earlier than their developed country counterparts, it is imperative that healthy lifestyles are promoted in school-age children. Educating adolescents about the optimal energy and fat intake and level of physical activity helps them to develop a healthy body and lifestyle and avoid overweight, obesity, and its comorbidities of hypertension and hyperlipedemia. Some researchers suggest that nutritional behavior is related to nutritional knowledge and that if an individual is educated on healthy eating, they will do this in practice [4, 7, 9, 10, 14]. Thus, nutrition education is an integral part of health education which will lead to disease prevention [1]. One of the main goals of universities is to broaden the knowledge of the people in a society, the enhancement of the nutrition attitudes, knowledge and practices of its students is of high importance, as this will subsequently lead to a more food conscious society and more healthy people [2]. Exercise is the master conditioner for the healthy and the major therapy for the ill, despite this; many children lead a relatively sedentary lifestyle and are not active enough to achieve these health benefits [3]. It is thus obvious that dietary intake, nutritional status, emotional maturity and physical fitness are major determinants of physical performance.

The purpose of the study was to test the nutritional knowledge gained. First, pretests were taken to understand the existing KAP. Then basic educational intervention was initiated by imparting nutrition education. The impact was later verified by posttests and compared between the two groups (athletes and non-athletes).

2 Methods and Subjects

2.1 Subjects

The study cohort, 300 athletes and 300 non-athletes belongs to different schools and sports ground of Nagpur city, Maharashtra, India with age group of 13–18 years was selected by stratified random sampling techniques. The athletes in the present study were state, national level athletes or playing for recreation or armature athletes who were on the sports ground daily at least for 1 h with varied sports disciplines.

2.2 Questionnaire Development

A well framed standardized questionnaire cum interview schedule was used to elicit information on demographic profile, nutritional knowledge, attitude, and practice with following three sections, i.e.,

- Fundamental concept of nutrition (FN) (10 questions/statements)
- Sports nutrition (SN) (10 questions/statements)
- Advanced nutrition (AN) (10 questions/statements)

A pilot study was conducted to estimate the reliability and validity of the same. This exercise was carried out to validate and improve the research instrument in terms of its format and layout, the wording of statements and also the overall content of items. Subsequent to this assessment, the study participants underwent training encompassing various aspects of the nutrition; its importance and utility in growth and development of the youth. The training was given with the aid of power point presentation and book developed and designed for the purpose. After successful completion of education programme, books were distributed among all students as a permanent source of information. To assess the effectiveness of the nutrition education, a post test was conducted to find out the change in knowledge, attitude and practice of adolescence (athletes and non-athletes) with respect to nutrition by using similar questionnaire after a week.

2.3 Procedure

Demographic information of the participants were collected by interview method whereas questionnaire related to knowledge, attitude and practice (KAP) were distributed to the participants after explaining them the purpose of the study and they were asked to solve the questions in front of the researcher.

2.4 Statistical Analysis

To determine the significance difference of nutrition KAP sections between pre- and posttest scores, a *Z* test for two means as well as two percentages was used. The comparative assessment of the effect of training on the KAP of athletes and non-athletes (*Z* test for two means) was also studied by calculating mean values. All statistical analysis was performed with use of SPSS for WINDOW.

3 Result

3.1 Demographic Information

Majority (more than 50%) of subjects lived in a nuclear family type. In view of their occupation, there did not appear any skewed behavior among the father's occupation while majority of the mothers' were a housewife with a meager percentage of them engaged in certain occupations. With respect to education, parents of majority of athletes were educated up to intermediate or Post-High School. However, in case of non-athletes group, parents of majority of subjects were educated up to graduation level. The results indicated that for the athlete and non-athlete group, the majority of parent's monthly income was between Rs. 20,000/- and Rs. 50,000/-.

3.2 Knowledge

Knowledge of study participants (athlete and non-athletes) with respect to nutrition show that before training, there was moderate to high level of awareness regarding the nutrition related aspects amongst athletes and non-athletes.

After undergoing training, there was a significant ($P < 0.05$) increase in the percentage of athlete boys (16–18 years) and girls (13–15 years), non-athletes boys of both the age groups and non-athlete girls (16–18 years) with high awareness of the total nutrition knowledge related aspects (Table 1). The percent change in the awareness of athlete and non-athlete boys (13–15 years) was between 5.3 and 52.0%, respectively. However, there was no significant difference between athletes boys (13–15 years) and girls (16–18 years), non-athlete girls (13–15 years) with high awareness of the total nutrition knowledge related aspects after training. But large variation (post training) can be attributed to the initial knowledge levels of athletes as well as non-athletes. The training program had a positive improvement in the knowledge levels of the athletes and non-athletes.

Table 1 Change in overall knowledge of nutrition due to training

	Athletes								Non-athletes							
	Boys				Girls				Boys				Girls			
	13–15		16–18		13–15		16–18		13–15		16–18		13–15		16–18	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Before training																
HA	38	50.7	40	53.3	22	29.3	45	60	10	13.3	29	38.7	27	36	22	29.3
MA	37	49.3	34	45.4	52	69.4	29	38.7	63	84	41	54.8	47	62.7	53	70.7
LA	0	0	1	1.3	1	1.3	1	1.3	2	2.7	5	6.5	1	1.3	0	0
After training																
HA	42	56	53	70.7	44	58.7	45	60	49	65.3	48	64	39	52	39	52
MA	33	44	21	28	30	40	29	38.7	26	34.7	25	33.3	35	46.7	36	48
LA	0	0	1	1.3	1	1.3	1	1.3	0	0	2	2.7	1	1.3	0	0
% change																
HA	*5.3*		*17.4*		*29.4*		*0*		*52*		*25.3*		*16*		*22.7*	
MA	−5.3		−17.4		−29.4		0		−49.3		−21.5		−16		−22.7	
LA	0		0		0		0		−2.7		−3.8		0		0	
Z-calculated	0.6		2		3.4		0		6		2.9		1.8		2.6	
P	*P* = 0.5 (NS)		<0.05		<0.05		*P* = 0.99 (NS)		<0.05		<0.05		*P* = 0.06 (NS)		<0.05	

Z-critical = 1.96
HA high awareness, *MA* moderate awareness, *LA* low awareness

3.3 Attitude

Attitude of subjects toward nutrition shows that before training, majority of non-athletes had moderate level of attitude toward the nutrition related aspects, while majority of athletes had a high attitude toward same. Comparatively, the total attitude of athletes was noticeably more favorable toward nutrition than the non-athletes. However, after undergoing training, there was no significant difference between athlete boys (13–15 and 16–18 years) and girls (16–18 years) and non-athlete boys (16–18 years), girls (13–15 and 16–18 years), with total attitude toward nutrition (Table 2). Whereas there was significant increase in the percentage of athletes girls (13–15 years) and non-athletes boys (13–15 years) with respect to total attitude toward nutrition. The percent change in the total attitude toward nutrition was between 1.3 and 38.7%.

3.4 Practice

Practice of the subjects in their day-to-day life with respect to their knowledge of nutrition was checked and the results showed that prior to training, significantly high percentage of non-athletes as well as athletes had moderate to high level of practice with respect to nutrition-related aspects and their use in daily life. Comparatively, there was no remarkable difference in the proportion of subjects in relation to practice of nutrition related concepts. However, after post training, there was no significance difference between athlete's boys (16–18 years) and girls (13–15 and 16–18 years) and non-athlete boys (13–15 and 16–18 years) and girls (13–15 years) with practice toward nutrition. Significant difference was found only in athlete's boys (13–15 years) and non-athletes girls (16–18 years) who indicated the use or practice of the knowledge related to nutrition in their daily life (Table 3). Although there was positive change, the magnitude of the change was lesser than the other aspects of practice.

4 Discussion

In this research, the training program had positive impact on the knowledge levels of the athletes and non-athletes with respect to nutrition. There was a significant ($P < 0.05$) increase in the percentage of subjects with high awareness of the above-mentioned topic, i.e., fundamental concepts of nutrition, sports nutrition, and advanced nutrition. Percent change in the awareness about nutritional knowledge was better amongst the athletes than the non-athletes. In the current research it was also observed that, post training, majority of athletes and non-athletes indicated that they use or practice the knowledge related to nutrition in their daily life. Although

Table 2 Change in overall attitude of study participants toward nutrition due to training

	Athletes								Non-athletes							
	Boys				Girls				Boys				Girls			
	13–15		16–18		13–15		16–18		13–15		16–18		13–15		16–18	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Before training																
HA	51	68	49	65.3	35	46.7	52	69.3	19	25.3	48	64	53	70.7	42	56
MA	24	32	26	34.7	39	52	23	30.7	55	73.4	25	33.3	21	28	33	44
LA	0	0	0	0	1	1.3	0	0	1	1.3	2	2.7	1	1.3	0	0
After training																
HA	55	73.3	52	69.3	49	65.3	51	68	48	64	55	73.3	49	65.3	48	64
MA	20	26.7	23	30.7	26	34.7	24	32	27	36	20	26.7	26	34.7	27	36
LA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% change																
HA	*5.3*		*4*		*18.6*		*1.3*		*38.7*		*9.3*		*5.4*		*8*	
MA	−5.3		−4		−17.3		1.3		−37.4		−6.6		−6.7		−8	
LA	0		0		−1.3		0		−1.3		−2.7		−1.3		0	
Z-calculated	0.6		0.4		2.1		−0.2		4.4		1.1		−0.6		0.9	
P	*P* = 0.5 (NS)		*P* = 0.6 (NS)		<0.05		*P* = 0.8 (NS)		<0.05		*P* = 0.2 (NS)		*P* = 0.5 (NS)		*P* = 0.3 (NS)	

Z-critical = 1.96
HA high attitude, *MA* moderate attitude, *LA* low attitude

Table 3 Change in overall practice of study participants with respect to nutrition and due to the training

	Athletes								Non-athletes							
	Boys				Girls				Boys				Girls			
	13–15		16–18		13–15		16–18		13–15		16–18		13–15		16–18	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Before training																
HA	28	37.3	33	44	45	60	45	60	37	49.3	33	44	35	46.7	23	30.7
MA	40	53.4	42	56	29	38.7	30	40	37	49.3	40	53.3	35	46.7	51	68
LA	7	9.3	0	0	1	1.3	0	0	1	1.4	2	2.7	5	6.6	1	1.3
After training																
HA	41	54.7	43	57.3	49	65.3	44	58.7	45	60	41	54.7	36	48	39	52
MA	34	45.3	32	42.7	26	34.7	31	41.3	30	40	34	45.3	39	52	36	48
LA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% change																
HA	*17.4*		*13.3*		*5.3*		*1.3*		*10.7*		*10.7*		*1.3*		*21.3*	
MA	−8.1		−13.3		−4		1.3		−9.3		−8		5.3		−20	
LA	−9.3		0		−1.3		0		−1.4		−2.7		−6.6		−1.3	
Z-calculated	2		1.5		0.6		−0.15		1.2		1.2		0.1		2.4	
P	<0.05		*P* = 0.1 (NS)		*P* = 0.5 (NS)		*P* = 0.8 (NS)		*P* = 0.2 (NS)		*P* = 0.2 (NS)		*P* = 0.8 (NS)		<0.05	

Z-critical = 1.96
HA high attitude, *MA* moderate attitude, *LA* low attitude

there was positive change, the magnitude of the same was lesser than the other aspects of as practice as individual needs time to convert his/her knowledge into practice. Kunkel et al. [6] and showed that the education leads to increase in the average scores of knowledge and attitude [5, 6]. In this study, the intervention in the form of training program had positive impact on the attitude of subjects (athletes and non-athletes) toward nutrition. There was a significant ($P < 0.05$) increase in the percentage of subjects with more favorable attitude toward nutrition-related aspects. Nutrition knowledge had a meaningful relationship with attitude and diet. Wong et al. [15] showed that there is a positive correlation between attitude and diet. According to the Schwartz [11] model of knowledge–attitude–practice which is based on the cognitive–affective–behavior theory in the area social psychology, the diet is related to the nutrition attitude and knowledge and subsequently nutrition practices.

5 Conclusions

The present study reveals that nutrition education intervention is vital among adolescence. It is important to accustom them to dietary pattern in different regions. Failure to consume right diet due to false belief and constant fear of eating prohibited foods may hamper performance. Hence, delivering continuous education through workshops and courses would help to improve teenagers' nutritional knowledge, attitudes, and practices. Efforts should be made to utilize the expertise of nutrition related experts in designing the diet of athletes involved in different types of sports. The school and college curriculum should incorporate the importance of different food items vis-à-vis general health of the adolescents.

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Chapter 11
A Study on Auditory Status of School Going Children Residing Near Railway Track

Chatterjee Sandipan, Chatterjee Ayan, Chatterjee Surjani, Santra Tanaya, Mondal Prosun, Banerjee Neepa and Mukherjee Shankarashis

Abstract With the increase in transportation of both men and material, railway transport noise is increasing; having significant influence on environment and human life and may affect the children being regularly exposed to it. In this backdrop, the present study was conducted to assess the impact of railway noise, if any, on auditory status and annoyance level of school going children residing and attending school near railway track. The study was conducted on 42 suburban and 30 urban adolescent females (age 16–18 years), respectively, constituting exposed group 1 and 2 (EG1 and 2) residing in and around Kolkata. 81 females of comparable age, residing in the relatively calm and quiet rural area constituted the control group (CG). The sound pressure level was recorded in different parts of the institutions, where the study was carried out. Audiometric assessment was carried out in comparatively calm and quiet room and the degree of hearing impairment was calculated. The annoyance level was assessed. The results indicate that, EG1 and EG2 individuals had significant ($P < 0.05$) hearing loss at low and high frequency compared to CG individuals. From the present study, it may be concluded that, school children residing in the vicinity of railway tracks are suffering from bilateral hearing impairment with adverse impact on their annoyance level.

Keywords Hearing impairment · Bengalee adolescent females · Hearing threshold · Traffic noise · Annoyance · Audiometry

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1 Introduction

School is an important micro-environment in children's life as they spend a considerable amount of time there everyday. Any environmental perturbation including noise in the vicinity has a chance of adversely affecting their cognitive development [1]. As along with urbanization, transportation facilities are also on the rise, increasing the number of highway and railway tracks at the vicinity of populated areas; even sometimes compromising with the public health issues and safety factors [5], noise, particularly from transportation, has become a serious concern [12, 13, 24, 26, 27, 30]. In this backdrop, present study has been conducted to assess the impact of railway noise, if any, on auditory status and annoyance level of female school going children residing and attending school near busy railway tracks in suburban and urban areas in and around Kolkata.

2 Methodology

On obtaining necessary permission from institutions located in and around Kolkata, the study was conducted on 42(n_1) suburban and 30(n_2) urban female individuals with age range 16–18 years, residing and attending schools near busy railway tracks, constituting, respectively, the exposed group 1 and 2 (EG1 and 2). 81(n_3) females of comparable age, permanently residing in the relatively calm and quiet rural area, far away from railway tracks and other sources of traffic noise constituted the control group (CG). Individuals with self-reported hearing difficulties were excluded from the study. Information about their age (years) and socioeconomic condition was recorded in predesigned schedule. Stature (cm), using anthropometric measurement kit, with an accuracy of 0.1 cm and body weight (kg), using weighing scale with an accuracy of 0.1 kg with participants in light clothing and without shoes, were measured and BMI was calculated. The sound pressure level was recorded in different parts of the concerned institutions by using sound level meter [3]. The background sound pressure level (SPL) of the audiometric room was checked periodically. Audiometric test was carried out [17, 25] with a portable audiometer for obtaining the hearing threshold at different frequencies (0.25–8 kHz) [23], for each individual at a time for both ears separately using the air conduction mode in pure tone. The hearing impairment status was assessed and degree of hearing impairment was calculated [16, 28]. The annoyance level, as reported, was assessed [2]. Obtained data were tabulated and used for further statistical analysis with the chosen level of significance being 0.05.

3 Results

Basic profiles of EG1, EG2, and CG individuals are presented in Table 1. There is no significant difference in terms socioeconomic status among EG1, EG2, and CG individuals.

The physical characteristics of the EG1, EG2, and CG individuals are presented in Table 2. There was no significant difference in terms of age and stature among EG1, EG2, and CG individuals but the body weight and BMI of EG1 and EG2 individuals was significantly lower ($P < 0.05$) compared to their CG counterparts.

In Fig. 1, the average hearing threshold in dB (A) at different frequencies for left and right ears of the EG1, EG2, and CG individuals has been graphically presented.

The bilateral hearing impairment status of the study participants as per WHO hearing impairment classification has been presented in Fig. 2.

In Fig. 3, the comparison between different degrees of hearing impairment status upto 2 and 4 kHz of EG1, EG2, and CG individuals, who are at least to some extent impaired, is graphically presented.

The percentage of annoyance status of impaired individuals of EG1, EG2, and CG has been presented in Fig. 4.

4 Discussions

Earlier studies have indicated that regular exposure to transportation noise including aircraft noise and traffic noise have negative impact on the auditory status of adolescent school going children [4, 7, 14, 19]. The results of the present study indicate that, 40, i.e., 95.2% of EG1 (n_1 = 42) and all i.e. 100% the EG2 (n_2 = 30) individuals have bilateral hearing impairment, whereas only 11 (13.5%) of CG (n_3 = 81) have bilateral hearing impairment at up to 2 kHz and up to 4 kHz. Moreover, it has been observed from the audiogram pattern of both left and right ear, that, the lower frequencies (0.5–2.0 kHz) have been affected more, compared to higher frequencies (4–8 kHz) indicating that there will be relatively poor hearing for low tones. For CG individuals, the average hearing threshold pattern of audiogram has

Table 1 Basic profile of the study participants

Demographic feature	EG1	EG2	CG
Residence	Suburban area, near busy railway tracks, Southern WB	Urban area, near busy railway tracks, Kolkata, WB	Rural area of Hooghly, WB
Religion, caste	Hinduism, general	Hinduism, general	Hinduism, general
School being attended	Public funded	Public funded	Public funded
Sample size	42	30	81

Table 2 Physical and physiological profile of EG1, EG2, and CG

	EG1	EG2	CG
Age (year)[a]	16.8 ± 0.77	16.8 ± 0.83	16.7 ± 0.74
Stature (cm)[a]	151.8 ± 5.5	155.3 ± 11.74	155.0 ± 7.75
Body weight (kg)*	41.7 ± 4.98	44.5 ± 13.32	47.3 ± 8.94
BMI*	18.5 ± 3.54	20.1 ± 3.33	22.2 ± 3.21

[a]ns
* $P < 0.05$

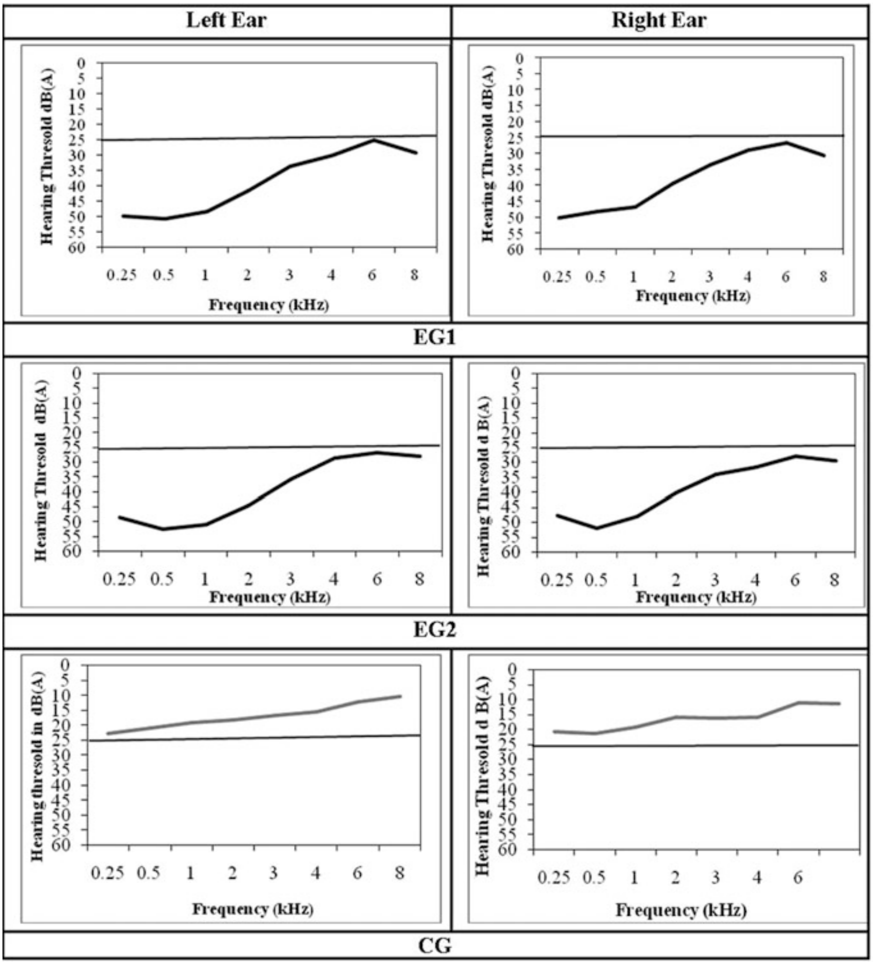

Fig. 1 Average hearing threshold in dB (A) at different frequencies (0.25–8 kHz) for left and right ears, of the EG1, EG2, and CG individuals

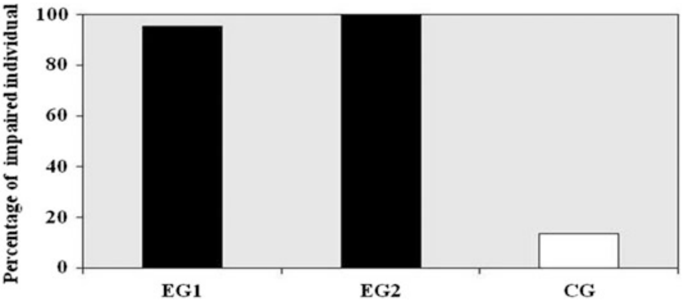

Fig. 2 Comparison between EG1, EG2, and CG individuals in respect of bilateral hearing impairment status as per WHO hearing impairment classification

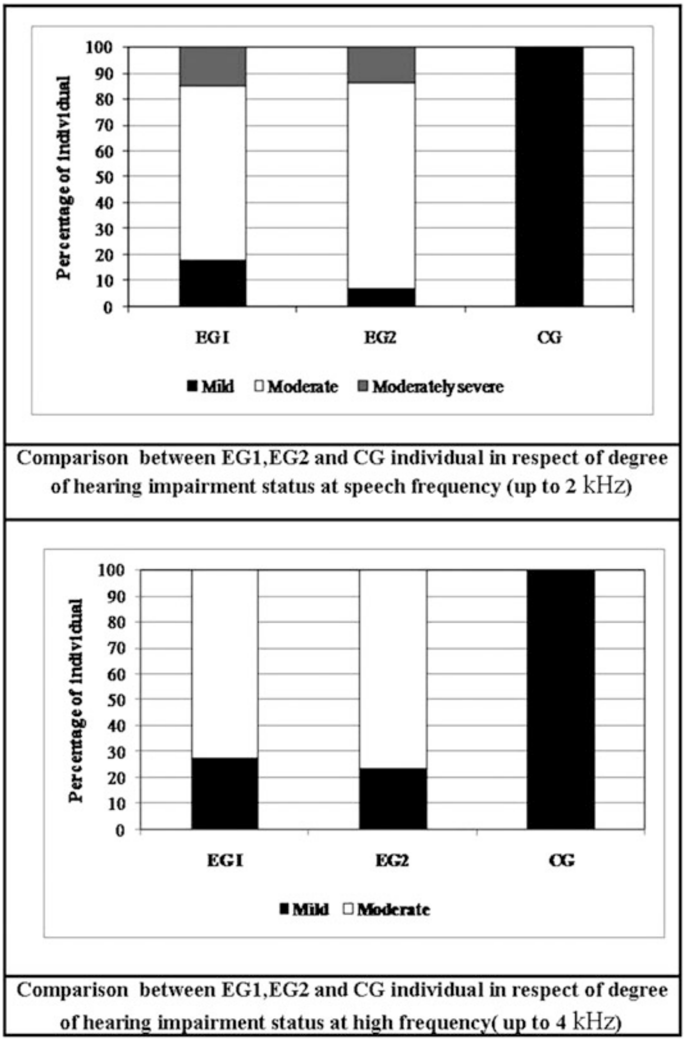

Fig. 3 Degree of Hearing Impairment status of EG1, EG2, and CG impaired individuals

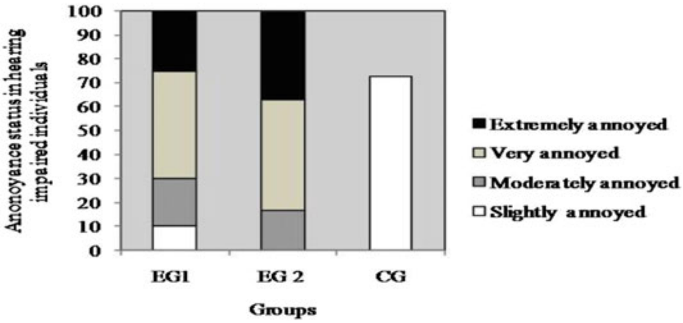

Fig. 4 Noise annoyance status of impaired individual of EG1, EG2, and CG

indicated that neither ear is affected at lower or higher frequencies (Fig. 1). Similar trend of result was observed in earlier studies among the rural children [6, 7, 18]. Significant difference ($P < 0.001$) has been observed among EG1, EG2, and CG individuals in respect of their bilateral hearing impairment status (Fig. 2). Similar trend of result was observed in earlier study carried on school going adolescents exposed to aviation noise [6, 7] and on occupationally engaged individuals exposed to industrial noise [8–11]. In the present study, there is significant difference ($P < 0.01$) in degree of hearing impairment status among EG1, EG2, and CG individuals. Among 40 EG1 and 30 EG2 impaired individuals, there is higher percentage, i.e., 67.5 and 80%, respectively, up to 2 kHz and 72.5 and 76.6%, respectively, up to 4 kHz, of 'moderate' degree of hearing impairment, whereas among 11 CG impaired individuals there is 100% of 'mild' degree of hearing impairment; the findings are in agreement with the findings of the earlier study conducted on adolescent children exposed to community noise [14]. Hence, the result of the present study indicates a relatively better auditory status among children residing and attending school in rural area of West Bengal [18].

Noise sensitivity is relative term attributed to personal ability and is a consistent predictor of noise annoyance [22]. Noise annoyance interferes with the daily activities and hence decreases the individual performance level including the educational performance. Studies have indicated that, traffic and aviation noise are also associated with annoyance [15]. In the present study significant difference ($P < 0.01$) has been observed between EG1, EG2 and CG individuals in respect of their annoyance status. Among 40 EG1 impaired individuals, 10% were 'slightly annoyed', 20% were 'moderately annoyed', 45% were 'very annoyed' and 25% were 'extremely annoyed'. On the other hand among 30 EG2 impaired individuals, 16.6% were 'moderately annoyed', 46.6% were 'very annoyed' and 36.6% were 'extremely annoyed'. Conversely among 11 impaired CG individual, only 72.7% individuals were found to be 'slightly annoyed'. The finding of the present study in agreement with the finding of an earlier study conducted on children exposed to high community noise [20, 21, 29]. Hence, the present study indicates that high level community noise, in the form of railway noise, has deleterious effect on hearing threshold level of children at speech frequency and also at 4 kHz which might have negative impact on their performance level.

5 Conclusions

From the present study, it may be concluded that school going female adolescents residing and attending educational institutions in the vicinity of railway tracks are suffering from hearing impairment and are having significantly more annoyance level, compared to their CG counterparts.

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Chapter 12
Assessment of Scapular Stability in Postpartum Females: A Longitudinal Study

Akhila Krishnakumar, Tejashree A. Dabholkar and Ajit Dabholkar

Abstract To maintain the center of gravity within the base of support during pregnancy, postural changes occur consequently affecting the thoracic spine. This study emphasizes the assessment of scapular stability in postpartum females and its impact on upper quadrant. Subjects ($N = 38$) were assessed immediately within the first week post-delivery and reassessed after 6 months. Strength testing of Trapezius, Serratus anterior and rhomboids with push–pull dynamometer along with pectoralis minor length, scapular index, lateral scapular slide test and yes/no test for scapular dyskinesis. Statistically significant change in scapular muscle strength and length was noted in females postpartum at the end of sixth month. Correlation was also found between personal characteristic of study population and scapular stability factors. Scapular stability factors shows significant changes in postpartum females.

Keywords Scapular muscle strength · Tightness · Postpartum

1 Introduction

Postural alignment during rest and movement has been proposed as an important part of musculoskeletal evaluation [7]. A scapular kinematics study accomplished that thoracic spine position significantly affects the scapula dynamics during scapular abduction and slouched position resulting in decrease in muscle forces [6].

A research stated that subjects with kyphosis and rounded shoulders had increased incidence of cervical, inter-scapular and headache pain [4]. Scapular stabilization

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requires coupling of the upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and rhomboid (Rmb) muscles along with the serratus anterior (SA) muscle [12].

Poor posture during breastfeeding could give rise to microtrauma or fatigue resulting in pain. This gives rise to the need to evaluate upper quadrant musculoskeletal involvement during the post birth period and its relation with changes occurring during pregnancy. Thus, to study scapular stability is imperative in post partum females.

2 Methodology

A longitudinal study for a duration of 6 months was conducted at D.Y.Patil Hospital, Maternity Ward/OPD, Nerul, Navi Mumbai on a sample size of 50 ($N = 38$, 12 dropouts). Primi gravid females of age group (15–30) were included who underwent full-term normal delivery (FTND) or lower segment cesarean section (LSCS). Subjects with any preexisting history of musculoskeletal pain or any medical conditions such as malignancy, gestational diabetes were not included in the study.

Approval for the study was gained from the Institutional Ethical Committee. Subjects were explained the purpose of the study and a written consent was taken from them. Demographic data like age, height, weight, and personal characteristic like breast feeding frequency (BF), weight gain during pregnancy (WG), and birth weight of infant (BW) were noted by a validated self-formulated questionnaire.

Outcome measures used in the studies were yes/no test [1], pectoralis minor length (PM) [9], lateral scapular slide test (LSST) [8], scapular index (SI) [2] shoulder pain and disability index (SPADI) [10], and Numerical Rating Scale (NRS) [5]. The muscle testing positions described by Kendall and McCreary [7] were adapted for use in sitting position with a Baseline hydraulic push pull dynamometer. The data was analyzed using Wilcoxon signed ranks test, where p values of <0.05 was considered significant (*).

3 Result

Subjects were evaluated within the first week (1 W) after delivery and at 6th months (6 M) postpartum. Age group included had a mean and standard deviation (SD) value of 23.3 ± 2.66 (mean $\pm$ SD). 63% of the subjects underwent FTND and 37% LSCS. Weight gain during pregnancy (8.73 ± 2.71) (mean $\pm$ SD) was noted. The subjective data passed the normality test.

4 Discussion

Percentage increase in prevalence of upper quadrant pain (35–39%) and decrease in lower quadrant pain (45–29%) was observed at 6 M evaluation. This change could be attributed to due to decreased load of the gravid uterus post-delivery and

Table 1 Prevalence of dyskinesis evaluated by yes/no test

Dyskinesia	1 W	6 M
Inferior border prominent (type I)	4	6
Medial border prominent (type II)	1	2
Superior border prominent (type III)	2	2
Symmetrical (type IV)	31	28

Table 2 Comparision of LSST between 1 W and 6 M

		Mean	SD	SEM	*p* value
Test position-1	Rt 1 W	9.739	1.273	0.2065	0.5171
	Rt 6 M	9.739	1.245	0.2019	
	Lft 1 W	9. 970	1.164	0.1888	0.7422
	Lft 6 M	9.703	1.164	0.1888	
Test position-2	Rt 1 W	8.339	1.065	0.1728	0.2149
	Rt 6 M	8.258	1.090	0.1769	
	Lft 1 W	8.153	0.981	0.1592	0.0934
	Lft 6 M	8.371	1.035	0.1678	
Test position-3	Rt 1 W	15.139	2.540	0.4120	0.0143*
	Rt 6 M	15.542	2.452	0.3978	
	Lft 1 W	15.134	2.605	0.4227	0.5598
	Lft 6 M	15.539	2.825	0.4582	

Standard error of mean (SEM)
* p value < 0.05 is statistically significant

increased upper limb functional demand. Our study results indicated prevalence pain up to 6 months postpartum [14].

Few subjects demonstrated dyskinesis with respect to the total population considered (cf Table 1). An increase in number of subjects with dyskinesis screened by LSST was noted at 6 M with maximum prevalence of type I dyskinesis [15]. Significant change of test position 3 on the right side could be attributed to majority of population being right dominant (cf Table 2). This could be due to various factors including, ligamentous laxity of the dominant side or postural malalignment that might be asymptomatic in individuals [8].

A research conducted exhibited that the group of subjects with shorter pectoralis minor length exhibited increased internal rotation and shorter Sternal notch to coracoid process distance [2, 6]. Both pectoralis minor length test and scapular index indicate extremely significant change in pectoralis minor length (cf Table 3). Indicating increased pectoralis minor tightness and abnormal scapular positioning on a transverse plane which could be due to adapted faulty position during feeding or increased anterior body weight due to pregnancy. Significant strength change with increase in mean values of bilateral upper trapezius was observed at 6 M (cf Table 4). Bilateral rhomboids and Rt lower trapezius strength change is also statistically significant, showing dip in their mean value at 6 M (cf Table 4). The above results form a pattern tending toward upper crossed syndrome [13].

Table 3 Comparison of pectoralis minor length between 1 W and 6 M

		Mean	SD	SEM	p value
Pectoralis minor					
Right	1 W	2.718	1.073	0.1741	0.001*
	6 M	2.955	1.025	0.1663	
Left	1 W	2.797	1.162	0.1885	0.001*
	6 M	3.066	1.177	0.1910	
SI					
Right	1 W	.9221	.07634	.01238	0.015*
	6 M	.9082	.08343	.01353	

* p value < 0.05 is statistically significant

Table 4 Comparison of Muscle strength between the 1 W and 6 M

		Mean	SD	SEM	p value
Pair 1	UT Rt 1 W	10.497	3.933	0.638	0.001*
	UT Rt 6 M	11.189	4.115	0.667	
Pair 2	UT Lft 1 W	9.691	3.638	0.590	0.043*
	UT Lft 6 M	10.063	3.698	0.599	
Pair 3	MT Rt 1 W	5.431	2.750	0.446	0.201
	MT Rt 6 M	5.102	2.542	0.412	
Pair 4	MT Lft 1 W	5.431	2.750	0.446	0.201
	MT Lft 6 M	5.102	2.542	0.412	
Pair 5	LT Rt 1 W	4.881	2.030	0.329	0.027*
	LT Rt 6 M	4.531	2.135	0.346	
Pair 6	LT Lft 1 W	4.939	2.133	0.346	0.105
	LT Lft 6 M	4.613	2.212	0.358	
Pair 7	SA Rt 1 W	8.495	3.704	0.600	0.731
	SA Rt 6 M	8.584	3.782	0.613	
Pair 8	SA Lft 1 W	8.126	3.757	0.609	0.156
	SA Lft 6 M	8.389	3.560	0.577	
Pair 9	Rmb Rt 1 W	4.9	1.522	0.250	0.001*
	Rmb Rt 6 M	4.437	1.603	0.263	
Pair 10	Rmb Lt 1 W	4.810	1.410	0.228	0.019*
	Rmb Lt 6 M	4.547	1.690	0.274	

* p value < 0.05 is statistically significant

Muscles positioned in either shortened or lengthened positions, will alter the efficiency of normal muscle contraction and thus cause the muscles to be used at a mechanical disadvantage which could be a causative factor for pain at upper quadrant in postpartum females [11].

Significant positive correlation of SPADI and birth weight, NRS and weight gain in pregnancy indicates more the infant weight and weight gain more would be the incidence of pain and disability (cf Table 5). In this study maximum (45%) subject breast fed their child four times in a day. SPADI scores had fair positive correlation with frequency of feeding not being statistically significant.

Table 5 Correlation of scapular stability at 6th month with personal factors

		Birth weight	Weight gain	BF
Pec. minor	Correlation value	0.380	0.256	.088[a]
	p value	0.076	0.136	0.601
SPADI	Correlation value	0.350*	0.042	0.304
	p value	0.031	0.803	0.064
NRS	Correlation value	−0.151	0.505*	0.067
	p value	0.564	0.039	0.799

		Birth weight	Weight gain	BF	PEC min[a]	SAPDI	LSST[a]	NRS
UT Rt	Correlation value	-0.223	0.012	−0.310	−0.412*	−0.115	−0.197	0.497*
	p value	0.178	0.941	0.058	0.038	0.491	0.236	0.042
UT Lft	Correlation value	−0.063	0.313	−0.068	−0.232	−0.066	−0.171	0.535*
	p value	0.706	0.055	0.686	0.230	0.696	0.304	0.027
LT Rt	Correlation value	0.103	0.180	−0.139	−0.367*	−0.302	−0.278	−0.313
	p value	0.539	0.280	0.405	0.017	0.045	0.091	0.221
LT Lft	Correlation value	0.130	0.040	0.026	−0.087	−0.253	−0.230	0.221
	p value	0.317	0.225	0.125	0.605	0.126	0.165	0.643
Rmb Rt	Correlation value	0.137	−0.023	−0.281	−0.340*	−0.189	−0.149	0.195
	p value	0.420	0.891	0.092	0.040	0.264	0.380	0.469
Rmb Lft	Correlation value	0.137	−0.031	−0.161	−0.287	−0.229	−0.190	0.217
	p value	0.411	0.852	0.334	0.092	0.167	0.252	0.404

[a]Bi serial correlation
* p value < 0.05 is statistically significant

Positive correlation of bilateral upper trapezius with pain intensity and significant negative correlation of bilateral rhomboids as well as dominant upper and lower trapezius muscle with pectoral length test was noted (cf Table 5). This supports that with increase in infant weight the mother exerts more effort to carry the baby leading to stooped posture that is associated with increased pectoralis minor tightness. Alternatively overuse of upper trapezius could lead to more lactic acid accumulation and localized fatigue becoming a causative factor of pain [3].

More over our study shows that most of the mothers fed mainly in sitting or lying posture (45%) and very few adapted ergonomically correct posture for feeding in the form of back support (18%). Thus, a need for awareness of ergonomics would decrease the prevalence of pain postpartum. Further, study can be conducted by assessing long-term effect of changed scapular behavior following postpartum.

5 Conclusion

Assessment of scapular stability in postpartum females showed increased pectoralis minor tightness, increased muscle strength of bilateral upper trapezius and decreased in strength of bilateral rhomboids and right lower trapezius. The study shows statistically significant change of scapular stability factor along with significant fair correlation between few personal characteristic of population.

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Chapter 13
General Health-Related Physical Fitness Levels of College-Going Girls from Maharashtra

P. Patel, Rauf Iqbal, H. Bhasin, A. Bhatnagar and M.K. Chauhan

Abstract The purpose of this study was to assess the General Health-Related Physical Fitness Levels of college-going girls of Maharashtra. For this purpose, 58 students were measured for Body composition (BMI, WHR and Fat.%), Muscular Strength (Hand and pinch, standing high Jump), Muscular endurance (Sit-ups, Push-ups and Trunk lift), Flexibility (Sit and Reach and Shoulder Stretch) and Aerobic Fitness (Queens College Step Test). Results indicate that around 52 and 21% of girls fell in Acceptable and Obese category of Body Fat.%. Girls demonstrated poor scores for hand and pinch strength, but performed averagely in standing high jump. It is crucial to note that girls had a lot of difficulty while performing Push-ups and Sit-ups, thus indicating poor muscular endurance. Majority of them were having good shoulder flexibility, but average low back flexibility. Aerobic test was not completed by 9% of girls and 14% had poor VO_2 max scores. Overall the health status of the girls needs to be improved in hand strength, muscular endurance, aerobic fitness and low back flexibility.

Keywords College girls · Body composition · Flexibility · Strength · Endurance and aerobic fitness

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1 Introduction

Physical Fitness is "ability to carry out daily task with vigor and alertness without undue fatigue and with ample energy to enjoy leisure time pursuits and to meet emergencies" [22]. Physical fitness is a set of attributes either health or skill-related. The degree to which people have these attributes can be measured with specific tests [4], normally non-invasive method [13]. Fitness helps to deal with health problems such as obesity, diabetes, osteoporosis, pain, cardiovascular disease, etc. [2]. Thus, it is important for people of all age to maintain an appropriate level of health-related physical fitness [21, 8].

Childhood and adolescence are crucial periods of life, where lifestyle and healthy/unhealthy behaviours are established during these years, which may influence adult behaviour and health status [21]. Overweight in children and adolescents are increasingly common [20, 23] while physical fitness in adolescents is declining [5, 14]. Lower fitness in adolescents may track into adulthood [18]. In India, little attention has been paid to the reducing levels of physical fitness. Hence, present study was piloted to assess the physical fitness levels of college-going girls.

2 Methods

The study was a cross-sectional descriptive type applying physical fitness tests on young college-going girls of Maharashtra. Anthropometric parameters and health-related physical fitness were assessed in 58 girls belonging to the age groups 18–24 years from various regions of Maharashtra (Dapoli, Latur, Pune, Nashik, Vajreshwari and Mumbai region). The participation was totally voluntary as only those girls who were ready to perform the tests were selected for the study.

2.1 *Physical Fitness Assessment*

Various fitness tests were adopted from FITNESSGRAM (The Cooper Institute) and Total Physical Fitness Program—TPFP, Kerala (Directorate of Sports and Youth Authority, Kerala), to measure the five health-related physical fitness components. Due to time constraint, each test was explained and a small trial was given.

Body Composition

BMI was computed [weight (kg)/height squared (m^2)] to classify participants into different categories (i.e. <18.5 underweight, 18.5–24.9 normal weight, 25–29.9 overweight and >30 obese). The WHR was calculated [waist/hip] and girls were classified as <0.75 excellent, 0.75–0.79 good, 0.80–0.86 average and >0.86 at risk [3]. Body fat percentage was measured using skinfold at Biceps, Triceps, Subscapular and Supra-iliac [6] and were classified based on Body Fat.%; 10–13%

essential fat, 14–20% athletes, 21–24% fitness, 25–31% acceptable and 32%+ obese (American Council on exercise guidelines).

Muscular Strength
Muscular strength of hands was measured by hand grip test (right and left) and pinch grip test (tip, palmar and key pinch) using Jamar dynamometer and maximum score (in kg) was recorded. Explosive strength of legs was measured by standing high Jump test (in cm) and categorized as follows: <11 very poor, 11–20 poor, 21–30 below average, 31–40 average, 41–50 above average, >50 good.

Muscular Endurance
Per minute count for Push-up and Sit-ups performed by participants was recorded. Upper body endurance was measured with Push-up test (bent-knees) and results was classified into: 0–1 very poor, 2–6 poor, 7–11 below average, 12–22 average, 23–29 above average, 30–36 good, >36 excellent [9]. Abdominal endurance was measured with Sit-ups (hands crossed on chest) and results was classified into: <18 very poor, 18–24 poor, 25–28 below average, 29–32 average, 33–36 above average, 37–43 good, >43 excellent [9]. Trunk lift test was used to measure trunk endurance and scores was classified as: <9″ poor and 9–12″+ as good [7].

Flexibility
Low Back Flexibility was recorded by Sit and Reach (1′ box with 23 cm marked at feet level) and Test scores (cm) were classified as: ≤ 7 very poor, 8–15 poor, 16–23 fair, 24–33 average, 34–43 good, 44–53 excellent, ≥ 54 superior. For Shoulder Stretch test, the participants were instructed to touch the fingers behind the back. If fingers touched comfortably or overlapping they were graded as ‘Very good’, fingertips just touching as ‘Good’ and fingertips not touching as ‘Poor’.

Aerobic Fitness
Aerobic Fitness was measured with Queens College step Test (stool height of 41.3 cm). VO_2 max (ml/kg/min) was calculated [17] and participants were graded [10] as: <36 poor, 36–39 fair, 40–43 good, 44–49 excellent, >49 superior.

3 Results

When the participants were classified as per BMI scores, it was found that 16 and 7% of them were ‘overweight’ and ‘obese’ respectively (Fig. 1). Similarly for Body Fat.% it was clear that 21% of girls were ‘obese’ (Fig. 2). When abdominal fat levels tested by WHR, it was noticed that 7% of girls were ‘at risk’ (Fig. 3; Table 1).

Girls demonstrated ‘poor’ scores in hand and pinch grip test (Table 2). In one of the studies [15] Mean (SD) of Hand grip (kg) data for females age 20–29 was 30 (7) and 28 (6.1) for right and left hand respectively. Similarly in another study [16], pinch strength data (kg) for females age 20–24, showed the Mean (SD) of Tip as

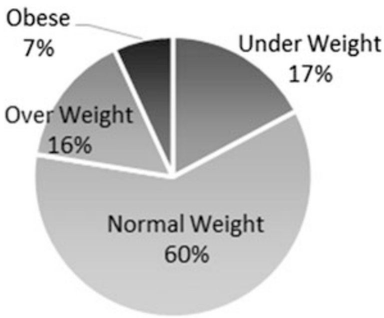

Fig. 1 Classification of girls as per BMI (n = 58)

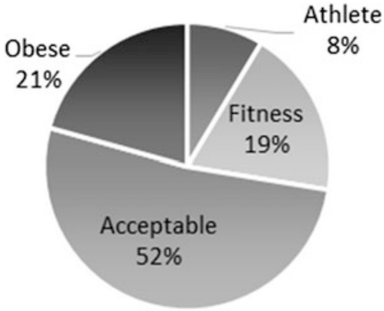

Fig. 2 Classification of girls as per body Fat.% (n = 58)

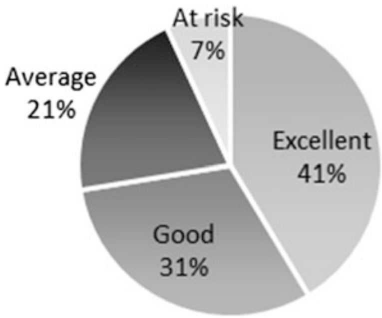

Fig. 3 Classification of girls as per WHR (n = 58)

Table 1 Demographic characteristics of college-going girls of Maharashtra (n = 58)

	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)	Body Fat.%	Waist (cm)	Hip (cm)	WHR (cm)
Mean	20.43	54.94	156.55	22.37	26.90	73.68	95.99	0.76
SD	1.46	11.79	5.66	4.58	4.98	12.33	10.73	0.06
Minimum	18	34	144	14.91	14.37	44	66	0.61
Maximum	24	89	172.6	35.1	38.6	107.5	122	0.93

Table 2 Hand and Pinch grip strength of college-going girls of Maharashtra (n = 58)

	Hand strength (kg)		Pinch grip strength (kg)					
	Right	Left	RT	RP	RK	LT	LP	LK
Mean	14.53	12.58	2.88	3.93	3.44	2.78	3.64	2.87
SD	3.89	3.67	0.72	0.81	0.88	0.67	0.73	0.78
Minimum	9	6	1.6	2.1	2.1	1.6	2.3	1.1
Maximum	21	21	5.3	5.5	6	4.3	4.9	4.7

Note *RT* right tip, *RP* right palmar, *RK* right key, *LT* left tip, *LP* left palmar, *LK* left key

Table 3 Fitness test score of college-going girls of Maharashtra (n = 58)

	Standing high jump (cm)	Push-ups (counts/min)	Sit-ups (counts/min)	Trunk lift (inches)	Sit and reach (cm)	VO_2 Max (ml/kg/min) by queens test
Mean	26.83	10.83	19.03	9.53	23.53	40.50
SD	5.34	7.42	9.14	1.46	7.73	4.57
Minimum	15	0	0	6	1	29.61
Maximum	39	30	41	12	38.5	49.21

5.03 (0.95), key as 7.98 (0.91) and Palmar as 7.80 (1.04). Thus, hand grip strength and pinch strength (Table 2) was found to be poor compared to the above studies.

Mean (SD) scores of Standing high jump was 26.83 (5.34) (Table 3) with around 90% falling in 'below average' and 'average' category. Modified push-ups with bent-knee was carried out as participants were not able to perform military style push-ups. Mean (SD) push-ups performed by the girls was 10.8 (7.42) (Table 3) with 34% girls demonstrating 'very poor' to 'poor' scores. Mean (SD) Sit-ups performed was 19 (9.14) (Table 3) with around 34 and 40% of girls demonstrating 'very poor' to 'poor' scores respectively. About 72.4% girls were able to comfortably perform the trunk lift test, and rest were graded 'Poor'.

Shoulder flexibility of almost 50% of girls was 'good', but more girls (15.5%) were found having poor score with left hand on top rather than right (3.4%). Low back flexibility of 83% of girls belonged to 'fair'–'average' category, with mean score of Sit and Reach being 23.53 cm (Table 3).

Mean (SD) of VO_2 max in ml/kg/ml was found to be 40.5 (6.09). The results showed that 9% of Girls could not complete test but others did fairly well with around 45% belonging to 'fair' and 'good' category.

4 Discussions

The results of the present study showed that according to BMI, 17% were underweight while 22% of girls belonged to overweight and obese category. Around 7% of girls were at risk due to abdominal fat level. Girls demonstrated poor scores for hand and pinch strength when compared to international study. Standing high jump test clearly showed that majority of girls (90%) were falling in below average and average category thus indicating poor level of explosive strength in legs. Muscular endurance tests confirmed that the girls had a great difficulty while performing Push-ups and Sit-ups. It is important to note that even after explaining the method of push-ups, the girls were not able to maintain the correct back posture while performing Push-ups. Overall, majority of girls had 'good' to 'very good' shoulder flexibility, but 83% of girls had average scores for low back flexibility with none of them in excellent and superior category.

One of the study concluded the total percentage of failures in Kraus–Weber Tests for Muscular Fitness and Flexibility has increased and this was attributed to mental stress [11]. Another study on female students of rural and urban set-ups in Delhi found that rural students were superior in strength, endurance, speed and agility, whereas urban female were heavier and superior in flexibility [12]. Another study also showed concern due to Poor level of cardio respiratory endurance in physiotherapy students [19]. Aerobic test in the present study was not completed by 9% girls and 14% had poor scores, thus making it a concern.

5 Conclusion

Overall, the current study showed that the general health status of the girls needed to be improved in hand and pinch strength, muscular endurance, low back flexibility and aerobic fitness. They have to keep a check on their body weight and waist line. It was found that hardly few girls were involved in regular physical activities as most of them were doing these fitness tests for the first time. Thus there is a need to improve the fitness of students by making changes in the curriculum. Our physical education needs a very definite expansion and active participation on a wider base [1]. Schools and colleges may play an important role by promoting positive health behaviours and encouraging them to be active.

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Chapter 14
Bagasse—A Replacement of Glass Wool as an Acoustic Material

Mohit Gaur, M. Muzammil and Abid Ali Khan

Abstract Present study was conducted to investigate and suggest a non-traditional material, in place of glass wool, which may be environmental friendly (green material) and may not harm the worker while performing the task. Bagasse, a green fibrous byproduct, obtained from the sugarcane stalks, was selected for study. The surface grinder (Make: Alex machine tool, Model No. H 208) selected in the present research generated a level of equivalent noise (Leq) in the range of 66.7–70.3 dBA. Two enclosures were designed for covering the grinder wheel and the working table with a 4 mm ply for bagasse fibers and glass wool which were spread in the annular space provided inside the enclosure and were put in place using steel wire mesh. The thickness of the fibrous layer of both the materials was taken to be 20 mm. The level of noise obtained using bagasse was 61.0 dBA while for fiber glass wool it was 64.3 dBA. The results of the study showed that there was a decrease of 6.6 dBA when bagasse was used as a noise-reducing material while a decrease of 3.3 dBA was obtained using glass wool.

Keywords Fibers · Bagasse · Glass wool · Noise control · Enclosure

1 Introduction

Several studies have shown that noise has significant negative effect on human health and work performance [1, 3]. In order to create a better working environment, there is a need to control the noise generated by various machines.

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Noise-absorbing curtains and bricks, walls, enclosures, mufflers, etc., are some commonly used passive control ways of reducing noise. Currently, commercially available materials for the acoustical treatment consist of glass wool, rock wool, or mineral-fiber material. These materials may pose serious threat to occupational safety of the worker as they have been found to have adverse effects on human health.

The importance of green materials has been recognized by various researchers in the recent past. Shenoda et al. [6] found that Egyptian cotton possessed a high sound absorption coefficient and could be used as an acoustical material. Fatima and Mohanty [4] found that jute was having better acoustical attenuation properties than glass fiber. Arenas and Crocker [2] while comparing Glass wool, ceramic, etc., with Cotton, Bagasse, and Jute found that later were more effective in decreasing noise.

Yang et al. [7] developed rice straw-wood particle composite boards capable of absorbing noise. A composite structure with a combination of perforated panel, rubber particle, porous material, polyurethane (PU) foam and glass wool, were found to demonstrate significant sound attenuation properties [5].

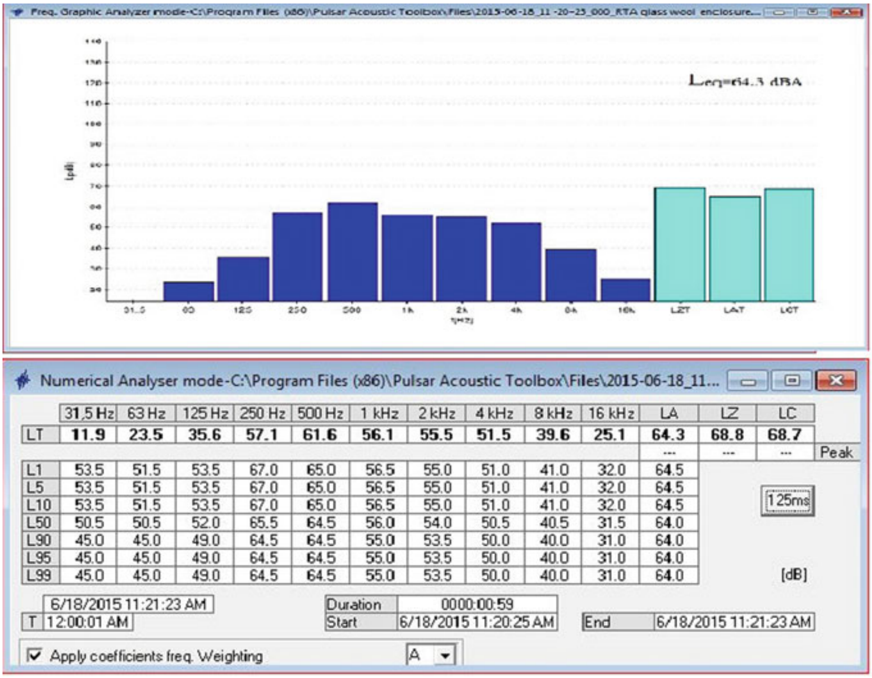
The literature reviewed revealed that non-traditional materials may be used in place of some widely used materials like glass wool. Hence in the present research, sugarcane bagasse was used as a noise absorbing material in place of glass wool.

2 Methodology

A surface grinder (Make: Alex machine tool, Model No. H 208) was used to study the attenuation of glass wool and sugarcane bagasse. An enclosure of 4 mm-thick ply board, having a dimension of 118 cm × 37.8 cm × 42 cm was designed to cover the table and the rotating abrasive wheel. The annular space provided on the inner walls was filled with a 2 cm thickness fiber layer of sugarcane bagasse uniformly. The volume available in the annular region between the ply and the steel wire mesh of the enclosure was 24,282.4 cm^3. The quantity of glass wool and bagasse used to fill this annular space was 3.5 and 1.4 kg respectively.

3 Result

Equivalent noise level (Leq) was measured using a noise level meter (Pulsar make: Model 33). The measurement of noise was done for a period of 1 min at a distance of 1 m from the machine where the operator was standing. Leq generated from the



	31,5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	16 kHz	LA	LZ	LC
LT	**11.9**	**23.5**	**35.6**	**57.1**	**61.6**	**56.1**	**55.5**	**51.5**	**39.6**	**25.1**	**64.3**	**68.8**	**68.7**
											---	---	---
L1	53.5	51.5	53.5	67.0	65.0	56.5	55.0	51.0	41.0	32.0	64.5		
L5	53.5	51.5	53.5	67.0	65.0	56.5	55.0	51.0	41.0	32.0	64.5		
L10	53.5	51.5	53.5	67.0	65.0	56.5	55.0	51.0	41.0	32.0	64.5		
L50	50.5	50.5	52.0	65.5	64.5	56.0	54.0	50.5	40.5	31.5	64.0		
L90	45.0	45.0	49.0	64.5	64.5	55.0	53.5	50.0	40.0	31.0	64.0		
L95	45.0	45.0	49.0	64.5	64.5	55.0	53.5	50.0	40.0	31.0	64.0		
L99	45.0	45.0	49.0	64.5	64.5	55.0	53.5	50.0	40.0	31.0	64.0		

Fig. 1 Frequency spectrum of sound power levels for a surface grinder with glass wool as an acoustic material

surface grinder was varying in the range of 67.6–70.3 dBA. The level of equivalent noise obtained with glass wool was 64.3 dBA while it was 61 dBA for Bagasse. When there was no enclosure applied, the noise level was 67.6 dBA.

Figure 1 shows the Sound Power Level octave band spectra within the same frequency range of 31.5–16000 Hz, the equivalent level values and the percentiles for each octave band for the surface grinder when glass wool was used as an enclosure material, enclosing the grinding wheel. It shows a reduction in the peak value and a decrease of value in the sensitive range of human hear and at higher frequencies.

Figure 2 shows the Sound Power Level octave band spectra within the same frequency range of 31.5–16000 Hz, the equivalent level values and the percentiles for each octave band for the surface grinder when bagasse was used as an enclosure material.

It shows a reduction in the peak value and a decrease of value in the sensitive range of human hear and at higher frequencies. The decrease in the values at each frequency was much higher as compared to glass wool.

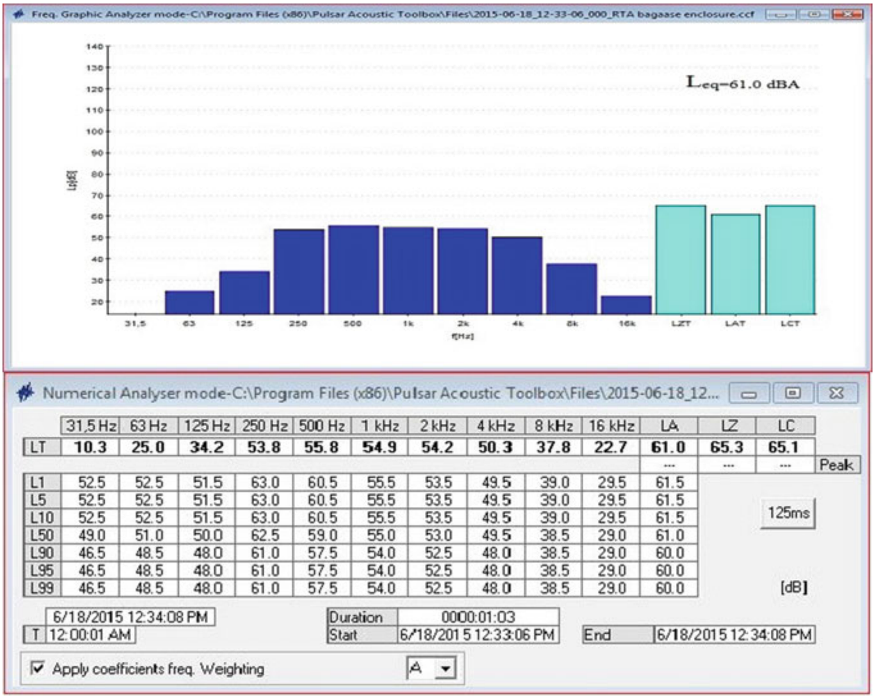


Fig. 2 Frequency spectrum of sound power levels for a surface grinder with bagasse as an acoustic material

4 Discussion and Conclusion

The results of the study showed that the use of sugarcane bagasse resulted in an overall decrease of 6.6 dBA of noise, while 3.3 dBA noise was reduced when glass wool was used. Though there was an increase in the values of noise levels at lower frequencies but this increase in the sound power levels in case of bagasse was much less when compared with glass wool. Moreover in the sensitive range of the human ear and at higher frequency, reduction in sound power levels was found to be more for bagasse. The results revealed that sugarcane bagasse has good acoustic properties at low and high frequencies. Hence, it may be satisfactorily be used as an acoustic material.

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Part IV
Occupational Ergonomics

Chapter 15
Manual Material Handling by Rural Women: An In-depth Analysis of the Body Pain Areas

Gupta Nidhi and Pupalla Padmaja

Abstract The daily work schedule of rural women is very demanding and arduous. The result is that the rural women are overburdened and subjected to potential health risk. The household work, manual material handling at work place, and animal care are not only strenuous but also the non-neutral posture of trunk frequently adopted by workers is a risk factor leading to exertion and spasm in the muscles. The studies for workers in unorganized sectors have yet to be intensified to equip them to face the grave realities. The present study aims an in-depth analysis of the body pain areas of the women handling manual material in rural sector. A descriptive research design with sample population consisting of 284 women in three talukas of Anand district were selected through stratified random sampling technique. Tool formation—the personal interview schedule consists of general and basic information and the intensity of pain is measured by the body mapping technique to assess the discomfort and musculoskeletal problems of the women. The intensity of body pain when analyzed through body mapping technique, it was found that it usually lies between severe pain to extreme pain while handling manual material. Majority of the women have suffered severe pain in lower extremity and the back (upper back and lower back), and one of the main reason could be because of the wrong posture adopted while doing work. Work-related musculoskeletal disorders due to manual handling (e.g., low back disorders) may have serious consequences on workers, and may restrict their ability to undertake a wide range of work and leisure activities for the remaining of their lives. This study aims to make fundamental changes in their work environment to tackle their fatigue levels.

Keywords Manual material handling · Body mapping · Posture analysis · Work analysis · Musculoskeletal problems

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1 Introduction

Having a healthy and quality working time, without injuries and inabilities is a general right and pre-condition for achieving sustainable development of any country [1]. Most of the rural women in India are burdened with household work, agriculture, childcare, and care of livestock which are arduous and demanding on time and energy. The handling of manual material is done in many ways such as lifting, reaching, repeating the same movements which may strain the body. Wear and tear of muscles, tissues, ligaments, and joints can injure the neck, shoulders, arms, wrists, legs, and back and these injuries are called musculoskeletal injuries.

There is substantial evidence that the neck and upper limb musculoskeletal injuries and back disorders are significant problem with respect to ill health and associated costs within the work place. To report the intensity of musculoskeletal discomfort experienced by radiographers concluded that intensity of pain increased as the day progressed and intensity of pain dipped in between the day break and increased by 5'o clock. Highest pain is experienced in lower back by the tallest people and the pain reported mostly on lower back, neck, and shoulders [2]. Recognizing the early signs is critical but necessary so that corrective measures can be implemented to avoid further damage and intervention measures can be provided if necessary. The work-related physical demands are primary risk factors and environmental conditions become secondary risk factors. The force that is exerted or repetition of forces leads to muscle fatigue and damage the tissue. This condition aggravates with unsuitable tools, tool handles, too larger or smaller objects and awkward positions [3]. A number of studies have found that women are at higher risk for work-related upper neck and limb disorders. It is found that the need of the hour is specific and sensitive diagnostic criteria for work-related musculoskeletal injuries [4].

There are number of ways to assess the muscular stress and these are:

(a) Intensity of pain in different body parts,
(b) Frequency of postural change, and
(c) Deviation of backbone from the normal.

For the present study the researcher measured the muscular stress through intensity of body pain following a proverb ‘A picture is worth a thousand words’. We all have heard this and as a tool to help figure out health and safety problems it turns out to be true [5]. The idea of body mapping is simple. It is a tool that health and safety experts and unions around the world are using to pinpoint the problems workers are facing and then using this information to figure out what in the workplace is causing these problems. With the diagram of human body drawn on paper we can survey the workers and mark on the place where it is hurting on the diagram. For many people it is easier to mark in a visual chart than using words to show where exactly it is hurting. Body mapping is not limited to aches and pains, workers will be able to mark if they experience headaches, allergies, etc., at work [5].

2 Objectives of the Study

- To measure the intensity of body pain experienced by women while working in MGNREGS through body mapping technique.
- To find out if there is any correlation existing between the age, education, years of experience in the profession and the help received at home for household chores with intensity of body pain endured by the women while working in MGNREGS.

3 Hypothesis of the Study

There exist no relationship between the intensity of body pain experienced by the selected respondents and their independent variables like age, education, years of experience, and the help received at home.

4 Methodology

An efficient and effective system which is a prerequisite for productive work depends on service delivered by human work force. So the concentration should be on the workers to eliminate the errors and improve health, safety, and productivity. This is an applied and analysis descriptive study in the field of MGNREGS by using descriptive questionnaire for analyzing the body pain through body mapping.

Phase-1: Sample selection
Phase-2: Tool selection

4.1 Phase 1: Sample Selection

For studying the quality of work life through body mapping technique the population selected was rural women working in Anand district under MGNREG Scheme. As for convenience, the sample population is selected from three talukas in Anand district which are more women concentrated and were drawn by stratified random sampling which consists of 284 women.

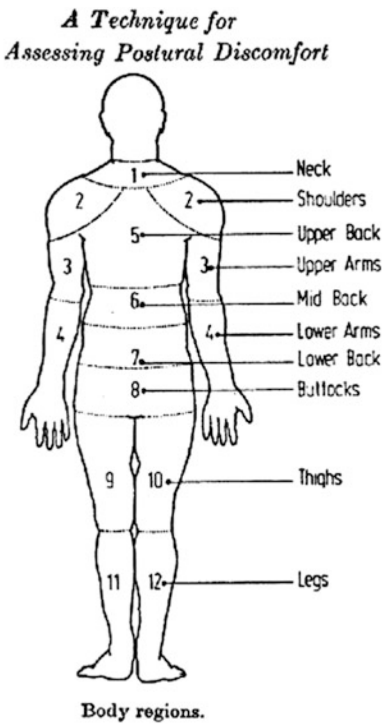
4.2 Phase 2: Tool Formation

By summarizing and considering the above issues and the review of literature a questionnaire for mapping the body pain through standardized body mapping technique by Verghese et al. [6] is used (Fig. 1).

The data was collected by using descriptive questionnaire which consists of general and basic information of the selected population in the first part. The second part of the data was collected by using the body mapping technique which included some ergonomic aspects while handling manual material to assess the discomfort and musculoskeletal injuries of the selected sample population.

Body Mapping Technique In this technique, the body is divided into a number of regions. Which indicates different body parts, viz., upper extremities (eye, neck, shoulder joint, upper arm, wrist, cervical and upper lumber) lower extremities (lower lumbar, buttocks, thigh muscles, knee joint, calf muscles, and ankles/feet). The scorecard showing the values from 1 to 5, viz., (1) very mild, (2) mild, (3) moderate, (4) severe, (5) very severe is used to quantify the stress on the muscles. After a bout of work the subjects are asked to indicate the body parts that are painful. After noting the painful parts the respondents are asked to indicate on a 5-point rating scale. The maximum intensity level of pain is given a rating of 5 (very severe), 4 for severe, 3 for

Fig. 1 Body mapping



moderate, 2 for mild, and for body part experiencing least pain the rating given is 1 (very mild/no pain). It is advisable that the data should be collected at the end of 2 h work period in case of light and moderate work. The body discomfort score of all the subject is added and averaged to get mean total score.

5 Results and Discussion

The first stage which consists of analyzing the basic information like the age, educational qualifications, years of experience in MGNREGS, number of family members and the help received from home for the household activities of the respondents is tabulated.

Basic Information of the Respondents
When the survey of the women working under MGNREGA was carried out through a structured questionnaire, the data revealed that more than half of the women, i.e., (60%) are illiterate and are in productive age group. One-third of the rural women were in the age group of 25–35 years while few of the respondents were in the age group of above 50 years. The three-fifth of the respondents had education in their childhood. It was observed that 48% of the women are working in MGNREGs since almost 5 years and 24% of women are working more than 5 years and 28% of women are working since 2 years.

In order to understand the dual role of the women and physical work carried out at home, the women were enquired about the work load at home. The data revealed that half of the women have 5–10 family members dependent on them, where more than half of the family members help in activities like child rearing, cooking, and collecting fuel wood. In the activities like fetching drinking water and for washing clothes women get the least help (Fig. 2).

Identifying the Body Pain Areas During Work Through Body Mapping Technique
On enquiry through personal interview schedule, we realized about the body pain experienced by women as depicted in Table 1.

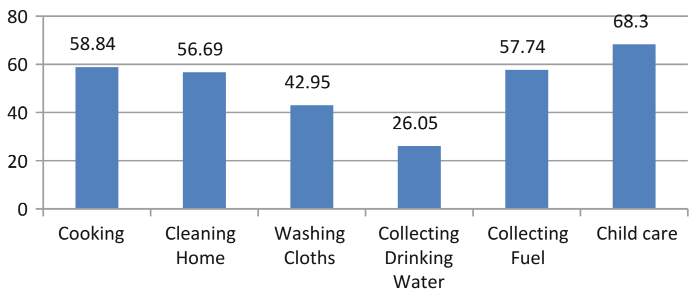


Fig. 2 Help received from family members in household work

Table 1 Intensity of body pain in the upper extremity

Sr. no.	Intensity of body pain	 No pain		 Mild pain		 Moderate pain		 Severe pain		 Extreme pain		MIS	S.D
		F	%	F	%	F	%	F	%	F	%	%	%
1	Head	49	17.25	12	4.22	19	6.69	36	12.67	168	59.15	3.91	1.54
2	Eyes	225	79.22	28	9.85	16	5.63	12	4.22	03	1.05	1.38	0.85
3	Ears	227	79.92	15	5.28	25	8.80	09	3.16	08	2.81	1.46	1.02
4	Neck	207	72.88	11	3.87	28	9.85	21	7.39	13	4.57	1.65	1.19
5	Clavicle right	158	55.63	24	8.45	37	13.02	43	15.14	21	7.39	2.09	1.39
6	Clavicle left	143	50.35	33	11.61	34	11.97	45	15.84	28	9.58	2.09	1.45
7	Left arm	74	26.05	18	6.33	39	13.73	72	25.35	81	28.52	2.45	1.55
8	Right arm	73	25.70	20	7.04	28	9.85	68	23.94	92	32.39	2.51	1.56
9	Left upper arm	128	45.07	29	10.21	40	14.08	41	14.13	45	15.84	2.61	1.59
10	Right upper arm	122	42.95	35	12.32	41	14.13	36	12.67	48	16.90	2.58	1.57
11	Left forearm	119	41.90	24	8.45	39	13.73	48	16.90	53	18.66	2.76	1.58
12	Right forearm	115	40.49	33	11.61	40	14.08	41	14.13	53	18.66	2.79	1.55
13	Left palm	103	36.26	29	10.21	43	15.14	49	17.25	58	20.42	3.95	1.37

MIS mean item score; *SD* standard deviation

The extreme body pain experienced by women (upper extremity) in the head region is 59.15%, 32.39% in the right arm, 28.52% in the left arm, 20.42% in the left and right palm each, 18.66% in the right and left forearm each, 16.90% in the right upper arm and 15.84% in the left upper arm, 9.58% in the left side of the clavicle and 7.39% in the right side of the clavicle, 4.57% in the neck region where as extreme pain near ears and eyes are negligible.

The percentage of women complained severe pain mainly in arms (25.35% left and 23.94% right), finger (23.23%), palm (17.25%), upper arms (14.13% left and 12.67% right) around 15% in the left and right clavicle, 12.67% near the head region, and 7.39% in the neck region.

As few women felt light to moderate pain, less than half of the women felt no pain at all. This may be because; out of 284 women around 160 of the women belong to 18–35 years age group and are habituated to work for long hours (Table 1).

The back is the most important part of the body in terms of postures while working. Through Table 2 we can clearly see that more than half of the women suffer with extreme pain in the back region, 53.87% lower back, 53.16% middle, and 40.14% upper back.

Most of the women felt severe pain than no pain at all in the low–middle back, while few women (around 13%) experienced mild to moderate pain in the back region. In a study on musculoskeletal discomfort the low back pain was in the peak discomfort level, followed by neck pain and shoulder pain. The results suggested that both the peak and cumulative discomfort could predict future musculoskeletal pain [7].

Table 3 depicts the intensity of body pain in the lower region. Most of the women, i.e., almost 70% are suffering with extreme pain mainly in the left and right thighs and buttocks (67.25 and 53.87%). Around 40 and 33% of women complained extreme pain in the left and right leg region respectively.

Some women (13–37%) did not experience any pain in the lower extremity while few Women around 5–10% experienced moderate to mild pain in the lower extremity.

The joints of the body should get the most attention for physical movement while working. The above table shows that 54–77.5% of women suffer **from extreme pain in the joints**. The highest percent of women (77–68%) complained **extreme pain mostly in the knee, elbows, and foot joints** (Table 4).

The intensity of body pain when analyzed through body mapping technique revealed severe pain to extreme pain in various body parts (Figs. 3 and 4). The selected women complained severe pain mainly in arms (25.35% left and 23.94% right), finger (23.23%), palm (17.25%), upper arms (14.13% left and 12.67% right) around 15% in the left and right clavicle, 12.67% near the head region and 7.39% in the neck region.

There is no significant (at 0.01 and 0.05 levels of significant) intensity of body pain experienced by the selected respondents and their independent variables like age, years of experience. However when the product movement co-relation was computed between intensity of body pain experienced by the selected respondents

Table 2 Intensity of body pain in the back

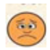
Sr. no.	Intensity of body pain	 **No pain**		 **Mild pain**		 **Moderate pain**		 **Severe pain**		 **Extreme pain**		MIS	S.D
		F	%	*F*	%	*F*	%	*F*	%	*F*	%	%	%
16	The upper	75	26.40	19	6.69	25	8.80	51	17.95	114	40.14	4.16	1.42
17	The lower	30	10.56	19	6.69	37	13.02	45	15.84	153	53.87	4.16	1.45
18	Middle	29	10.21	30	10.56	33	11.61	41	14.43	151	53.16	4.13	1.47
Total												**4.15**	**0.02**

Table 3 Intensity of pain in lower extremity

Sr. no.	Intensity of body pain	No pain		Mild pain		Moderate pain		Severe pain		Extreme pain		MIS	S.D
		F	%	F	%	F	%	F	%	F	%	%	%
19	Left buttocks	65	22.88	21	7.39	18	6.33	27	9.50	152	53.52	3.09	1.73
20	Right buttocks	38	13.38	09	3.16	12	4.22	33	11.61	191	67.25	2.92	1.74
21	Left thigh	41	14.43	06	2.11	14	4.92	25	8.80	197	69.36	3.83	1.54
22	Right thigh	43	15.14	06	2.11	15	5.28	25	8.80	193	67.95	3.91	1.57
23	Left leg	90	31.69	31	10.91	33	11.61	20	7.04	109	38.38	4.26	1.37
24	Right leg	104	36.61	29	10.21	24	8.45	29	10.21	94	33.09	4.27	1.38
Total												3.72	0.16

MIS mean item score; *SD* standard deviation

Table 4 Intensity of pain in the joints

Sr. no.	Intensity of body pain	No pain		Mild pain		Moderate pain		Severe pain		Extreme pain		MIS	S.D
		F	%	*F*	%	*F*	%	*F*	%	*F*	%	%	%
25	Left shoulder	50	17.60	12	4.22	28	9.85	37	13.02	155	54.57	3.26	1.57
26	Right shoulder	51	17.95	13	4.57	14	4.92	34	11.97	170	5.98	3.32	1.59
27	Left knee	21	7.39	09	3.16	14	4.92	31	10.91	208	73.23	4.39	1.19
28	Right knee	18	6.33	09	3.16	13	4.57	24	8.45	220	77.46	4.47	1.14
29	Left elbow	33	11.61	08	2.81	14	4.92	22	7.74	204	71.83	3.05	1.55
30	Right elbow	36	12.67	05	1.76	11	3.87	22	7.74	207	72.88	3.38	1.66
31	Left foot	43	15.14	07	2.46	11	3.87	26	9.15	194	68.30	4.14	1.47
32	Right foot	55	19.36	08	2.81	09	3.16	13	4.57	199	70.07	4.05	1.61
Total												3.75	0.59

MIS mean item score; SD standard deviation

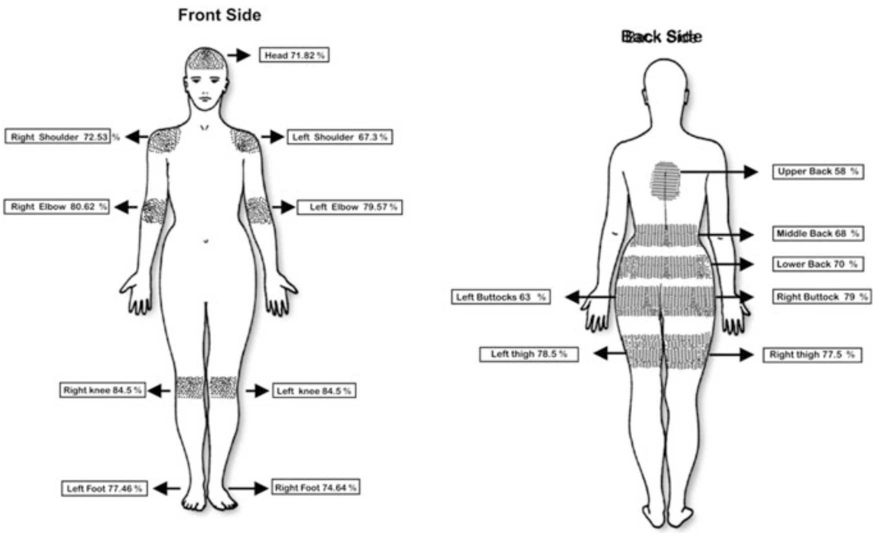


Fig. 3 Severe/extreme body pain in various body parts of women working under MGNREGA through body mapping technique

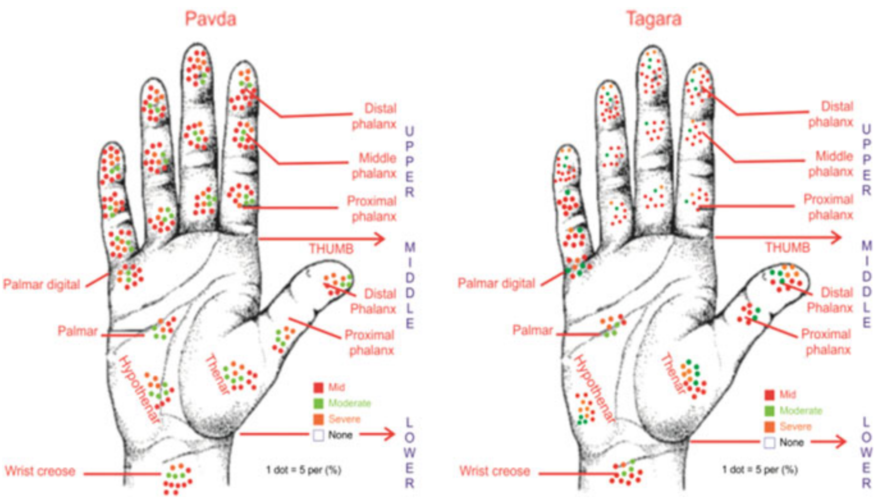


Fig. 4 Percentage of pain areas of right hand of women working under MGBREGA with hand tool

and the help received by them for the household tasks from the family members revealed a significant relationship (0.05 level of significance) specifically intensity of body pain in upper extremities (0.05) and the joints (0.05) was found positively co-related with the help received by the respondents.

All the rural working women had suffered various body pains. Majority of the women have suffered severe pain in lower extremity and the back (upper back and lower back), and one of the main reasons could be because of the wrong posture adopted while doing work [8].

6 Conclusions

Work-related musculoskeletal disorders due to manual handling (e.g., low back disorders) may have serious consequences on workers, and may restrict their ability to undertake a wide range of work and leisure activities for the remaining of their lives.

This study aims to target the rural women to make them aware of their capabilities, tolerances, and limitations in respect to their demanding work and to make fundamental changes in their work environment to tackle their fatigue levels.

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Chapter 16
Characterization of Drudgery of Farm Women in the Soybean Production System

Jayshree P. Zend, Manjusha S. Revanwar and Sandhya N. Admankar

Abstract A sample of 50 farm women involved in soybean production system was selected from five villages of Parbhani district. Pretested interview schedule was used to collect the data. The activities performed by the farm women in selected production system were listed out. Six variables were selected for characterizing drudgery of women in selected three production systems such as Physical load, Postural load, Repetitive strain load, Time load, Musculo skeletal Discomfort load, and Physiological load. Drudgery index was calculated based on total drudgery load. Drudgery index was identified as medium to high in case of soybean production system. Significant variation was observed due to factors contributing to drudgery of women labourer in soybean production system. The study revealed that drudgery of women labourers in Soybean cultivation is characterized by physiological, physical, and repetitive strain load experienced due to lack of protective aids and appropriate technologies. Result emphasized the need of designing cost-effective tools/implements, techniques based on ergonomic consideration.

Keywords Drudgery index · Load factors · MSD · Physiological load Postural load

1 Introduction

Agriculture is an important unorganized sector when majority of the women labour force is engaged. Farm women suffer from musculoskeletal problems that are caused by over use of muscles and significantly impair their activities of daily living [7]. Over the year's women cultivators are typically and wrongly characterized as economically inactive and women cultivators play only a supportive role in

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agriculture as farmers' wives [6]. Dash [2] stated that the Indian women, especially in the poverty group spend above 5 h per day more than the Indian man in work, including visible burden of family. As per the recent findings women in India are major producers of food in terms of value, volume, and number of hours worked. In the view of Chayal and Dhaka [1] the farm women's participation was maximum in cutting, picking, cleaning grains, drying of grains, storage, processing operations and major part of cleaning of field, raising nursery for seedlings, weeding, shifting production to threshing floor, winnowing and grading operations are also done by farm women. In case of leveling of field, fertilizer application they do least amount of work, where as there is no participation of farm women in ploughing of field, plant protection measures and marketing activities.

Marathwada region is the largest area under soybean cultivation. Most drudgery prone tasks are performed by women in soybean cultivation. Thus, present study was taken up with the objectives to assess drudgery in women-dominated activities.

2 Methodology

The present study was conducted in selected villages of Parbhani district. A total of 50 women farmers engaged in soybean production system from last 5 years were selected purposively. Interview schedule was used for collecting general background information and to elicit information on drudgery involved in women-dominated activities in soybean production system. Drudgery in soybean production system was calculated as per the six parameters, i.e. physical load, posture, repetitive strain, physiological load, musculoskeletal disorder, time load and load factor. Each factor was measured using quantitative and qualitative methods [3–5].

Drudgery load and drudgery index were calculated for each selected activity in selected crop system by using following formulae:

$$\text{Drudgery Load} = [\mathrm{dr(PL)} + \mathrm{dr(P)} + \mathrm{dr(RS)} + \mathrm{dr(T)} + \mathrm{dr(MSDs)} + \mathrm{dr(PysL)}]$$
$$\text{Drudgery Index } \% \text{ (DI)} = [100 \times \mathrm{dr(total)}]/150$$

where,

dr (total) = Total drudgery; PL—physical load (25 points); P—postural load (25 points); RS—repetitive strain load (25 points); T—time load (25 points); MSDs—musculoskeletal disorders (25 points); PhsL—physiological load (25 points) [3, 5].

Drudgery-Level Categorization

<15 = V. Low, 15–30 = Low, 30–45 = Moderate to Heavy, 45–60 = Heavy, 60–80 = V. Heavy and >80 = Unacceptable.

3 Result

Soybean production system was studied in Parbhani district and it was found that all soybean farms were rain fed. Total duration of soybean crop was 3 months. Intercultural operations and weeding were performed after 1 month of sowing, i.e., in the month of July and August. Activities exclusively performed by women were removing stalks, stubbles, weeding and transportation of manure. Equal participation of men and women was observed in activities such as spreading of manure, seed dropping, cutting, gathering and heaping. Traditional iron weeder (*Khurpi*) and sickle (*weela*) were used for weeding, harvesting, gathering and heaping by women. Physical load up to 25 kg was being lifted at 1.4 m height and handled for a distance of 2 km while gathering and heaping soybean harvest. Similarly, about 6 kg physical load was being handled by women while transporting and spreading of manure. Though more man hours were spent in weeding and harvesting, time load contributed to only 12–13% of variation in drudgery load. Repetitive strain loads were felt more in weeding, cutting, removing stalk and stubbles and gathering and heaping soybean harvest in the fields.

Activity of soybean cutting had high drudgery load, and it was followed by weeding plant to plant and gathering and heaping which were categorized as moderate to heavy tasks. Table 1 showed that physical load followed by repetitive strain load and physiological load contributed to drudgery of farm women in the order of priority. Repetitive strain load was higher in weeding, soybean cutting, gathering and heaping and removing stalks and stubbles. Drudgery due to physical load was more in transportation and spreading of manure and gathering and heaping. Drudgery due to physiological load was more in transportation and spreading of manure, weeding and soybean cutting. Significant variation in drudgery was found due to factors computed by ANNOVA (Figs. 1 and 2).

4 Conclusion

It can be concluded that among all the selected eight activities, cutting soybean plants was scored highest for its drudgery load and bagging soybean seeds at field was scored least. It can be said that as extent of participation of farm women was higher in performing cutting soybean plants, drudgery load was perceived higher. Whereas bagging at field was a male-dominating activity and role of women was only to assist them, hence, drudgery load was perceived less.

Table 1 Drudgery load of farm women in soybean production system

Farm activity	Physical load (25)	Posture load (25)	Repetitive strain load (25)	Physiological load (25)	Time load (25)	MSD load (25)	Total drudgery (150)	Drudgery index (%)	Level	'*F*' value
Removing stalks and stubbles	8.6	7.2	14.8	11.06	12.8	6.3	61	40.6	MH	33.97*
Transportation of manure	18.2	4.6	6.3	15.6	7.1	9.1	61	40.7	MH	81.28*
Application of manure	17.3	7.2	7.2	15.4	5.7	6.8	60	40	MH	63.61*
Seed dropping	10.8	4.4	9.9	11.2	7.3	9.4	53	35	MH	17.01*
Weeding	4.4	14.3	17.6	13.1	8.5	7.04	65	43	MH	76.81*
Soybean cutting	8.9	11.6	15.6	13.7	10.6	7.2	68	45	H	20.99*
Gathering and heaping	13.1	9.4	13.5	12.1	8.8	7.06	64	43	MH	15.09*
'*F*' value	60.98*	51.99*	50.52*	6.48*	15.79*	3.44*				

H Heavy; *MH* Moderate to heavy; *MSD* Musculoskeletal disorder
*Significant at 5 % level

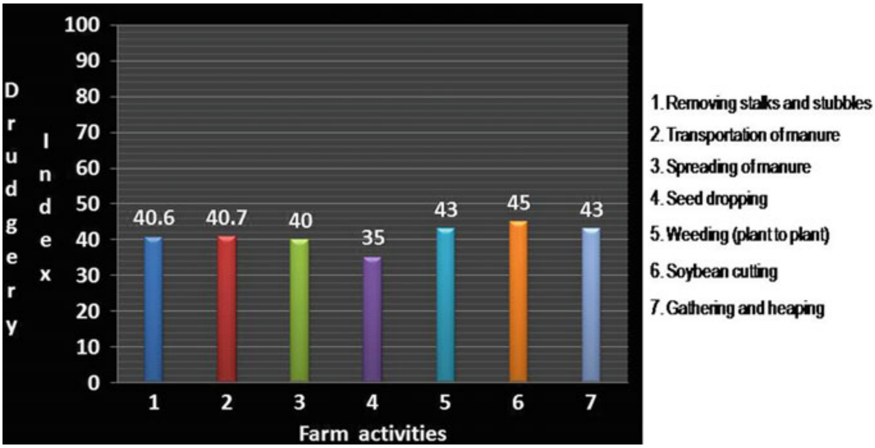

Fig. 1 Drudgery load of farm women in soybean production system

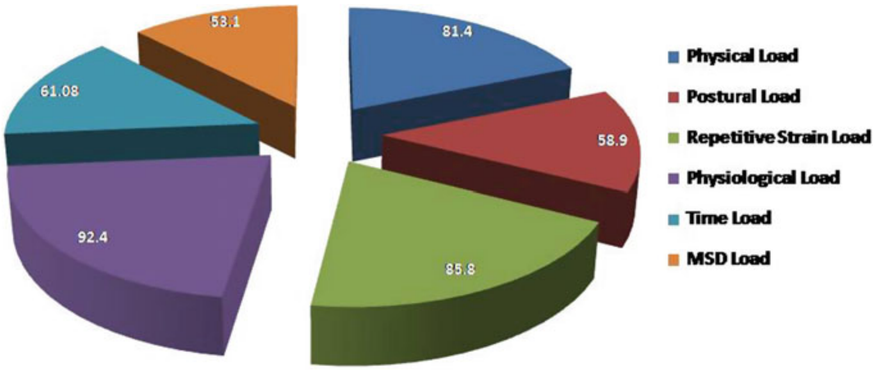

Fig. 2 Factors contributing to drudgery load of farm women in soybean production system

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Chapter 17
Association of Job and Demographical Risk Factor with Occurrence of Neck Pain Among Hand Screen Printing Workers

S. Shankar, R. Naveen Kumar, P. Mohankumar, J. Karthick and S. Pradeep

Abstract The objective of this study was to examine the prevalence of neck pain and to explore its association with individual job and demographical risk factors among hand screen printing workers. These factors include gender, age, marital status, smoking and drinking habits, willingness of the workers, sick leave, working efficiency and experience. A questionnaire survey was taken among the 385 working labours with different age groups in the western part of Tamil Nadu. The result shows that the prevalence of neck pain among the workers of the hand screen printing was about 27.8%. The female workers, higher age group workers, married workers and higher experienced workers seem to have a higher MSD and discomfort. This study statistically illustrates the effect of job and demographic factors on neck pain among hand screen printing workers.

Keywords Neck pain · Screen printing · Repetitive task · Sick leave · Work posture · Cross-sectional study

1 Introduction

Neck pain (NP) is a major communal health problem, both in terms of personal health and overall being as well as indirect expense [1]. In cross-sectional studies, neck pain had been associated with poor general health status, psychological disorder, and history of neck injury, in addition to other factors such as occupational tasks and obesity [2, 3]. Hand screen printing work was a labour-intensive work which involves repetitive tasks, prolonged standing, and maintaining awkward and uneasy posture which causes musculoskeletal disorders [4]. These workers were affected by MSDs due to their work nature and different postures being followed.

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An investigational evaluation of the association of the risk factors with the occurrence of neck pain among hand screen printing workers was performed in this study. The main purpose of this study was to assess, the prevalence of neck pain among the hand screen printing workers and significant relationship between the demographical, job risk factors and MSDs. The aim of this study was constrained to HSP industry as it had poor ergonomic conditions, poor work conditions and practices.

2 Methods

2.1 Subjects

Three hundred eighty-five workers from different Hand Screen Printing (HSP) industries were selected as subjects for this research. Only workers with no history of accidents, surgery or bone dislocation, were taken for the study. Printing was the major work in the Hand Screen Printing industry (Fig. 1). Apart from this work, preparatory works such as buying and transporting the bundle of clothes, attaching the clothes with the table, checking off the dye ink colours, drying the printed clothes were also carried out. The total time of these works were nearly 10 h a day and total working days in a week were 5–6 days.

2.2 Data Collection

The sample size of this cross-sectional study was determined by the Cochran's sample size for an infinite population with 95% confidence interval and 5% error margin [5]. The data were collected using Modified Nordic Musculoskeletal Questionnaire which was done similar to the studies [6, 7]. The first section of the

Fig. 1 Printing process in HSP industry

questionnaire was based on workers' background such as age, gender, work experience and personal habits such as smoking and alcohol consumption. The next section was based on the psychological factors such as willingness in the job, etc. In the next section (medical-section) chronic diseases, respiratory problems, sick leave, surgery and bone dislocation were taken into considerations. In work-related information rest time, length of the cloth, standing hours, awkward posture, frame weights and repetitive work were discussed.

3 Results

3.1 Description of the Sample

The 385 workers were in age group range from 20 to 60 (mean 35.08 ± 5.85). Among them, 54.8% were male and 45.2% were female. The work experience ranges from 1 to 15 years (mean 6.28 ± 2.33). It was noted that 315 workers were married (81.8%) and 70 were unmarried (18.2%).

The results obtained from the report showed that 62.5% of the subjects were affected by the musculoskeletal disorder in the past 12 months and out of these 27.8% were affected by MSDs in the neck region. The workers had very less smoking habits (n = 66, 17.1%) and alcohol consumption was also less (n = 72, 18.7%). More than half the population of subjects' discomfort mildly affected their work efficiency (n = 219, 56.9%) and for few, it was moderate (n = 111, 28.8%).

3.2 Prevalence of Neck Pain and Its Associated Factors

From the Table 1, it is evident that gender, smoking, alcohol consumption, willingness, marital status, work efficiency and sick leave were statistically significant with neck pain. Some other factors include age group less than 30 years and workers with 11–15 years' experience were statistically associated with neck pain. The number of subjects affected by neck pain was grouped based on gender and marital status and shown in Fig. 2. In the 27.8% (n = 107) of workers who reported neck pain, 8.6% (n = 33) were male and 19.2% (n = 74) were female (OR 1.923, 95% CI 1.572–2.352). Table 1 shows the relationship between various independent risk factors and neck pain.

In the sampling population, 5.2% of workers fewer than 30 years of age (OR 0.449, 95% CI 0.260–0.774), 11.19% of workers within the age group 31–40 years (OR 1.431, 95% CI 0.899–2.276) and 11.43% of workers above 40 years (OR 1.504, 95% CI 0.944–2.396) were affected by neck pain. Considering the marital status, the married workers were greatly affected by neck pain (OR 1.208, 95% CI 1.114–1.310). It was also noted that nonsmokers were critically affected by neck

Table 1 Prevalence of neck pain with individual risk factor

Independent risk factors		Neck pain (27.8 %)			
		N	%	OR	95% CI
Gender	Male	33	8.6	0.482	0.358–0.648*
	Female	74	19.2	1.923	1.572–2.352*
Age	<30 years	20	5.20	0.449	0.260–0.774*
	30–40 years	43	11.19	1.431	0.899–2.276
	>40 years	44	11.43	1.504	0.944–2.396
Marital status	Single	7	1.82	0.289	0.137–0.610*
	Married	100	25.98	1.208	1.114–1.310*
Experience	Less than 5 years	17	4.42	0.790	0.435–1.436
	6–10 years	24	6.23	0.826	0.484–1.410
	11–15 years	31	8.05	1.837	1.096–3.078*
	More than 15 years	35	9.10	0.836	0.519–1.345
Smoking	Smokers	10	2.61	0.481	0.255–0.906*
	Non smokers	97	25.19	1.130	1.037–1.231*
Alcohol consumption	Yes	13	3.38	0.568	0.326–0.990*
	No	94	24.42	1.120	1.019–1.232*
Willingness	Yes	93	24.16	0.902	0.834–0.976*
	No	14	3.64	3.394	1.592–7.237*
Sick leave	Yes	24	6.24	1.939	1.205–3.120*
	No	83	21.56	0.874	0.781–0.979*
Working efficiency	Not affecting	1	0.27	0.043	0.006–0.316*
	Mildly affecting	43	11.17	0.389	0.247–0.615*
	Moderately affecting	59	15.32	5.342	3.286–8.864*
	Severely affecting	4	1.04	0.963	0.927–0.999*

* Statistically significant

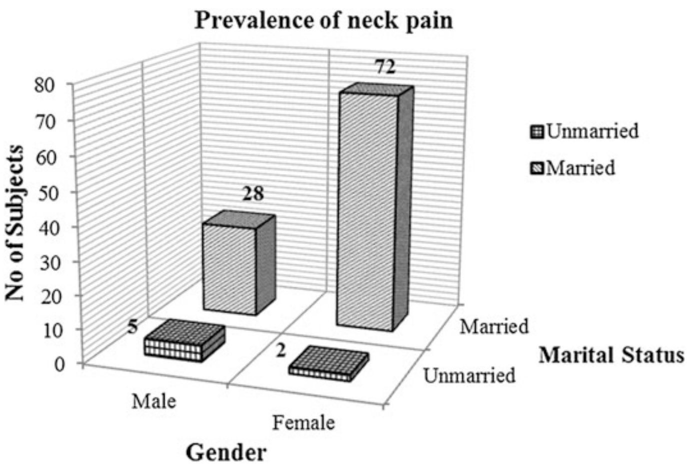

Fig. 2 Number of subjects affected by neck pain

pain (OR 1.130, 95% CI 1.037–1.231). The workers with alcohol consumption had lesser neck pain (OR 0.568, 95% CI 0.326–0.990). The willingness of the worker had adverse effect on neck pain, the subjects without willingness (OR 3.394, 95% CI 1.592–7.237) had severe neck pain. The subjects who availed sick leave were affected by neck pain (OR 1.939, 95% CI 1.205–3.120). The workers with 11–15 years of experience had a drastic effect on neck pain (OR 1.837, 95% CI 1.096–3.078). By visual inspection, the probability of causing MSD increased with increase in experience. Nearly 15% of the total population reported that the neck pain moderately affected (OR 5.342, 95% CI 3.286–8.864) their working efficiency.

4 Discussion

Table 1 shows the result of risk factors suppose to cause MSDs in neck anatomy. The statistical analysis showed that there was a significant relation ($p < 0.05$) between gender, age, marital status, smoking, alcohol consumption, higher experience group, willingness, sick leave, working efficiency and neck pain.

In the present study; out of 385, 107 (27.8%) subjects reported neck pain in past 12 months and majority was females 74 (44.5%). The women working in the HSP industry were homemakers and they perform daily household works which involves awkward posture, heavy physical work and frequent lifting, and it supposed to cause MSD in neck regions [8].

In our study, the subjects, with experience 11–15 years were affected by neck pain (OR 1.837, 95% CI 1.096–3.078). The findings of this study also indicated a significant association between the job duration and the neck pain, which was similar to studies on the operators in computer telephone interactive tasks [9].

The relationship between MSD prevalence and age was pointed out in previous studies [10]. Basically, as work experience and age increase, the strain accumulates and hence the prevalence of MSDs was higher among older workers [11, 12]. In this study, older workers reported a significantly higher frequency MSD symptom of the neck. Thus, the workers above 40 years of age suffered from neck pain (OR 1.504, 95% CI 0.944–2.396). The married subjects were suffering more neck pain when compared to those who were unmarried. The reason was that the married subjects were more prone to stress due to socio-economic conditions [13] and the family burden, which increases the workload and thus increasing the muscle fatigue in neck regions. Sick leave and willingness of the worker to work also had a significant relationship between neck pains in this study. Moreover this HSP job was a labour-intensive work and thus heavy physical and psychological load at work had been shown to be associated with sickness absence as it can cause neck pain [14]. If worker is not willing to work, the workload is increased psychologically which affects the physical work and induces stress.

A study stated that musculoskeletal disorders result in loss of work efficiency among dental surgeons and musculoskeletal pain and fatigue may influence posture control which can increase the risk of errors and may result in low work efficiency [15]. Similarly, the HSP workers' MSDs influence their working posture and thus reduce the working efficiency.

5 Conclusion

The Hand Screen Printing workers had a prevalence of musculoskeletal pain and discomfort in neck anatomy which highlights the need for ergonomic interventions for improving the condition of the HSP group. From the statistical report, independent risk factors including gender, smoking habits, alcohol consumption, willingness of the worker, availing of sick leave, working efficiency and marital status of a worker had greater significance ($p < 0.05$). In order to reduce the occurrence of neck pain among HSP workers, the HSP workers should be advised to reduce the duration of the time spent per day (working hours) by taking regular rests, breaks and performing variety of job than a single variety and take regular exercises. Thus, interventions could help in removing the external factors associated with the disorder considered.

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Chapter 18
Effect of Fatigue on Hand Function in Dental Profession

Tejashree A. Dabholkar, Riddhi Shroff, Ajit Dabholkar and Sujata Yardi

Abstract Dental professionals are at the high risk of fatigue in upper quadrant area. Hence, this study aims at assessment of the muscle behaviour of dentists during isotonic postures while performing various dental procedures. Twenty dentists participated in the study. Assessment of hand parameters like grip, pinch strength and dexterity was done in the beginning and end of work day. Development of muscle fatigue was assessed by surface electromyography of two forearm muscles i.e. Flexor Carpi Ulnaris (FCU) and Extensor Carpi Radialis Longus (ECRL). Statistics done by spectral analysis (median frequency). It was found that the median frequency decreased significantly in the forearm muscle. Hand function namely, grip ($P < 0.0001$), pinch ($P < 0.0001$), dexterity ($p < 0.0001$) has also shown significant decline over a period of time. Study conclude that overuse of forearm muscle work had influenced hand function significantly.

Keywords Fatigue · Forearm muscles · Hand function · Electromyography

1 Introduction

In the dental profession, dentists and dental hygienists spend their work days in an awkward, static position performing extremely precise procedures in a smaller workspace—the patient's mouth. Because there is no room for error, a steady hand

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and a steady, awkward posture must be assumed and maintained. However, maintaining the steady hand and posture comes at a cost of fatigue and discomfort. Several studies have indicated that back, neck and shoulder pain are a major problem among dentists. It was discovered in the field study [7] that dentists were experiencing pain on the outside (lateral) of the upper forearm just below the bend of the elbow. This tenderness hinders such activities as gripping and lifting. The pain suffered by dentists may lead to reduced productivity in terms of missed time from work or reduced work hours and may also lead to inefficient movements while working, causing an increase in time spent per patient. However, the development of fatigue is best observed by amplitude and spectral analysis of EMG readings [8, 9]. Studies suggesting that the forearm fatigue distribution is probably of great importance for the understanding of forearm disorders related to muscular exertion are available [10]. Forearm fatigue could lead to reduced hand function.

2 Methodology

Subjects' selection: professionally active dentists were studied. Total 20 dentists involving 9 female and 11 male subjects were included in the study (Table 1).

Electromyography (EMG) is the study of muscle function through analysis of electrical Signals emanated during muscular contractions [1]. The muscle fatigue index is represented by the median frequency of the spectrum. Two forearm muscles namely flexor carpi ulnaris and extensor carpi radialis longus is selected for data collection. The measurements were taken during the course of full working day starting with the first patient at 8:30 a.m. and ending with the last patient at 3:00 p.m. Repeated measures analysis was used to determine if fatigue occurred in the forearm muscles over time. Borges scale was used to assess amount of discomfort felt during working. Assessment of hand function parameters like grip, pinch strength and dexterity was done in the beginning and end of working hours.

Manual dexterity—Jebsen hand function test was used to assess manual dexterity. Grip strength and pinch strength can be assessed using hand held dynamometer and pinch meter respectively. Examining the amount of muscle activity associated with dental work and determining if fatigue is reached at the end of a patient's procedure or at the end of the day was done by using repeated measures mixed model analysis with a five percent level of statistical significance.

Table 1 Demography of study population

Variables	All subjects	Male	Female
Age	32 ± 1.17	31 ± 1.16	30 ± 1.18
BMI	28.48 ± 1.87	27.88 ± 1.25	25.21 ± 1.85
Practicing years	5.49 ± 1.46	5.6 ± 1.23	4.89 ± 1.5
Practicing hours	8.36 ± 1.86	8.23 ± 1.45	7.51 ± 1.52

3 Results

See Tables 1, 2, 3, and 4.

4 Discussion

For testing the Hypotheses for EMG Field Observations the EMG measurements for the forearm muscles were considered as the Dependent variable in a repeated measures mixed model with time as a fixed effect. Time was found to be significant, with a *P* value of 0.0092, so the least-squares means for each time were compared to determine which times were significantly different (Tables 2, 3). It was

Table 2 Least squares means for time effect (ECRL)

Hypothesis	Mean difference	*q* value	Adjusted *p* value	Lower 95% CI	Upper 95% CI
μ1ECRL = μ2ECRL	1.856	3.925	<0.05*	0.684	3.62
μ1ECRL = μ3ECRL	3.533	7.471	<0.001***	1.762	5.304
μ1ECRL = μ4ECRL	5.805	12.276	<0.001***	4.034	7.57
μ2ECRL = μ3ECRL	1.677	3.54	>0.05#	−0.094	3.448
μ2ECRL = μ4ECRL	3.949	8.35	<0.001***	2.178	5.72
μ3ECRL = μ4ECRL	2.272	4.80	<0.01**	0.501	4.04

Not significant
* Significant
** very significant
*** Extremely significant

Table 3 Least squares means for time effect (FCU)

Hypothesis	Mean difference	*q* value	Adjusted *p* value	Lower 95% CI	Upper 95% CI
μ1FCU = μ2FCU	2.229	3.142	>0.05#	−0.428	4.886
μ1FCU = μ3FCU	4.181	5.893	<0.001***	1.524	6.838
μ1FCU = μ4FCU	5.72	8.062	<0.001***	3.063	8.377
μ2FCU = μ3FCU	1.952	2.751	>0.05#	−0.705	4.609
μ2FCU = μ4FCU	3.491	4.92	<0.01**	0.833	6.148
μ3FCU = μ4FCU	1.539	2.16	>0.05#	−0.118	4.196

μ1 = mean MDF electrical activity in the muscle at the beginning of the first patient's procedure;
μ2 = mean MDF electrical activity in the muscle at the end of the first patient's procedure;
μ3 = mean MDF electrical activity in the muscle at the beginning of the last patient's procedure;
μ4 = mean MDF electrical activity in the muscle at the end of the last patient's
Not significant
* Significant
** very significant
*** Extremely significant

Table 4 Effect of fatigue on hand function and muscle activity of forearm

	Pre	Post	Diff	*p* value
Grip	36.76	34.19	2.57	<0.0001***
Pinch	18.81	14.71	4.09	<0.0001***
Dexterity	45.53	48.24	−2.71	<0.0001***
Median frequency FCU	141.40	135.86	5.54	0.0016***
Median frequency ECRL	132.67	126.76	5.91	<0.0001***

Not significant
* Significant
** very significant
*** Extremely significant

determined That the measurements during the last minute of the first patient visit of the day were significantly Higher than both the first and last minutes of the last patient visit of the day. This signifies a Decreasing shift in median frequency, which is a sign of fatigue.

Study shows significant difference between pre and post score of JHFT (P value < 0.0001), Grip and pinch strength (Table 4), the possible reason for reduced hand function may be changes in the local metabolism at muscle [4]. Pedersen et al. [11] reported that increased intra muscular concentrations of lactic acid, bradykinin, arachidonic acid and serotonin after fatiguing contractions may affect the muscle spindle system and proprioceptive acuity and thus may alter the functional activity. Djupsjobacka et al. [5] in separate study reported that increased intra intramuscular concentrations of several contractile substances alter the muscle spindle output as measured through reflex arc. Study of "dysfunctional mechanoreceptor" theory proposed by Voight et al. [13] states that muscle fatigue desensitized muscle spindle threshold thereby decreasing the afferent feedback to the central nervous system. Barnes [2] found that forearm blood flow was maximum with contractions of 20–25% MVC and declined thereafter. Hence, muscle contraction is compromised in fatigued muscles which may be the possible reason for increased JHFT score.

As fatigue progresses, the number of active motor unit decreases, muscle fibre conduction velocity decreases [6]. Motor unit fires more slowly [3] and the motor units become more asynchronized, This leads to decreased mean frequency of electromyogram (EMG) signal and eventually to task failure. Muscle fatigue may impair a person's ability to properly execute a task. MRI studies showed increased activity in the prefrontal areas of the brain after muscle fatigue, which may explain increase in processing time [12]. Studied the effects of induced fatigue on brain activity during sensorimotor control. EEG gave results of significant decrease in frontal theta, alpha-1 and alpha-2 frequencies after inducing fatigue these components are important for processing information thus may lead to increased reaction time. This study has shown significant difference in MVC (P value 0.0001). MVC has decreased drastically post fatigue. Decline in isometric force production is characteristic of skeletal muscle fatigue.

5 Conclusion

This study indicates that the median frequency decreased significantly in the forearm muscle from the last minute of the first patient to both the first and last minutes of the last patients. Hand function has also shown significant decline over a period of time.

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Chapter 19
Cardiac Stress Among Two Types of Handloom Weavers

Santu Durlov and Subhashis Sahu

Abstract Handloom is one of the traditional cottage industries in India. In West Bengal, a large number of rural populations are engaged in it. Mainly two types of looms are used in unorganized sectors, viz., traditional handloom and newly developed Jacquard loom. In both cases the job is manual in nature, which causes cardiac stress. Thus the present study was aimed to evaluate the cardiac strain of two groups of handloom weavers. Sixty male handloom weavers of at least 3 years of experience were randomly taken from different areas of Nadia district in West Bengal, India. They were categorized into two groups, i.e., handloom weavers and jacquard loom weavers based on the type of loom they use. The study was performed during the period of February to April, 2015. Polar heart rate monitor was used to measure the resting, working and recovery heart rates. Cardiac stress indices like net cardiac cost (NCC), relative cardiac cost (RCC), etc. were calculated in both groups of workers. The different cardiac parameters, i.e., NCC, RCC, average working heart rate (AWHR), and energy expenditures, were significantly ($p < 0.05$) higher among jacquard loom weavers than the normal handloom weavers. Because jacquard loom work is very stressful, it also requires proper training and greater paddling force. AWHR was found to be 119.28 ± 5.69 and 144.53 ± 11.51 beats/min in the normal and jacquard loom weavers, respectively, and are also statistically significant. Maximum working HR of the jacquard loom weavers (144.53 ± 11.53 beats/min) was significantly ($p < 0.05$) more than that of the handloom weavers (119.28 ± 5.69 beats/min). So, with the introduction of new work aid, Jacquard machine in loom increases the productivity but also increases the cardiac stress. So the optimal balance should be formulated.

Keywords Handloom weavers · Cardiac stress indices · Jacquard loom weavers

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1 Introduction

Handloom is one of the traditional cottage industries in India. In West Bengal, a large number of rural populations are engaged in the handloom industry. It is the long-standing cottage industry of the state, as the handloom products have great demands in India and abroad. Handloom weavers belong to a very low socioeconomic class [19]. These male handloom weavers are the only earning member of their family. It is a traditional occupation where the son learns to weave from his father.

Exports of handloom textile have made steady progress in the competitive textile world of today. The different varieties of handloom products are now exported to more than 120 countries all over the world. India is the highest handloom producing country in the world [17]. It is estimated that there are about 4.60 million handlooms in the world out of which about 3.9 million are in India [9].

Weaving appears to be a very simple but in reality it involves meticulous processes and stages, involving a number of ergonomic risk factors like awkward posture, high force, repetitiveness, long duration of work, and high visual demand. Weaving involves a number of stages, but for study purpose weaving activities have only been considered, as this is the major task component [7].

Moreover, the workers have to work in a hot, humid, congested, and in poorly ventilated workplace. Mainly two types of looms are used in unorganized sectors, viz., **normal handloom** and **Jacquard loom**. The **Jacquard loom** is a mechanical loom that simplifies the process of manufacturing textiles with complex patterns as brocade, damask and matelasse. The loom is controlled by a "chain of cards", a number of punched cards, laced together into a continuous sequence. Multiple rows of holes are punched on each card, with one complete card corresponding to one row of the design, whereas a **handloom** is a simple machine used for weaving. In wooden vertical-shaft looms, the heddles are fixed in place on the shaft. The warp threads pass alternately through a heddle, and through a space between the heddles (the shed), so that raising the shaft raises half the threads (those passing through the heddles), and lowering the shaft lowers the same threads—the threads passing through the spaces between the heddles remain in place [10]. In both cases the job is manual in nature, which causes cardiac stress, but there is dearth of data regarding the cardiac stress among these weavers. The present study was aimed to evaluate the cardiac strain of these two groups of handloom weavers.

2 Materials and Methods

2.1 Participants

The study group consisted of sixty handloom weavers with at least 3 years of working experience. The exclusion criteria are the weavers that are older than

45 year of age and those that are suffering from any type of chronic illness. They were divided into two groups based on the loom used.

2.2 Study Period and Task Design

This study was done from February to April, 2015, from 7:00 to 14:00 h. For the first 1.5 h, they were acquainted with the study protocol and some data were collected about the job, physical profile, resting heart rate (HR), etc. They filled up the consent form for the study. The weavers were then asked to perform the experimental task, i.e., to work their normal handloom activity for 30 min. The study was conducted on their actual workstation.

2.3 Physical Profile

Body height and weight were measured with a standardized anthropometric rod and properly calibrated weighing machine, respectively. From those data, body mass index (BMI) [14] was calculated.

2.4 Physiological Parameters

2.4.1 Resting, Working, and Partial Recovery HR

Heart rate (HR) was recorded with a heart rate monitor (Polar Accurex Plus, Polar Electro Oy, S810i, Finland). Resting HR was measured before the participants performed their task. Working HR was recorded every minute up to 30 min of work, and partial recovery HR was recorded up to 20 min just after cessation of work.

2.4.2 Predicted Maximal HR

Predicted maximal HR of the participants was calculated from their respective ages [11].

2.4.3 Average Working HR

Average working HR was derived from the value of the fourth minute of work onward [13].

2.4.4 Percentage of Reserved HR

Percentage of reserved HR for average working HR and working maximal HR was calculated from the predicted maximal HR for respective ages [20].

2.4.5 Cardiac Strain

NCC and RCC were considered as two derived indices of cardiac strain and were thus calculated [4].

2.4.6 Work Strain or Sum of Recovery Heartbeats (SRHB)

SRHB is a measure of work strain, which was calculated by summating the values of HR during the partial recovery period of 20 min for each participant.

2.4.7 Percentage of Recovery (PREC)

PREC was calculated from the ratio of fall in HR during the recovery period as a percentage of the increment of working over resting HR [15].

2.5 Blood Pressure

Resting and working blood pressure was measured with the help of properly calibrated aneroid sphygmomanometer by Auscultatory method.

2.6 Statistical Analysis

Statistical analyses were done among the different groups of workers as their physiological responses to the experiment. Student *t* test was done with two types of different groups (Group 1 and 2) of handloom weavers with control by means of their work demand, work category, and cardiac strain. It has been proved by the difference and significant level under the p value of 0.0001 ($p < 0.0001$) [5].

3 Result and Discussion

The physical profile of two groups of handloom weaver is given in Table 1. It was observed that both groups are of similar age and experience of work. But height and weight slightly differ between the two groups.

Here BMI value is varying and it ranges from 24.09 ± 2.88 (Group 1) and 20.29 ± 2.33 (Group 2), where all the mean value of the working individual is in the normal range. This indicated that the weavers did not have any chronic energy deficiency (CED). But very few of them are underweight ($n = 2$).

The comparison of cardiac strain indices is given in Table 2. It was observed that NCC, WHR max, etc. are significantly more in Jacquard loom workers.

Maximum working heart rate (WHR_{max}), NCC, and Energy expenditure (EE) of the two groups of weavers vary significantly ($p < 0.05$) with more cardiac stress on the Jacquard loom weavers. It was seen that the jacquard loom weavers surpassed the recommended limit of cardiac strain indices like NCC and %RCC. As the NCC and %RCC were higher among the jacquard loom weavers, this might be due to the effect on metabolic function of the body and also over reduction of the muscle power. So they were unable to work with same effort for long period due to exertion of extreme physical and environmental condition. This indicated that the job of the Jacquard loom weavers was heavy in nature as per the guidelines proposed by Astrand and Rodhal [1]. As this work is very stressful and heavy in nature [6], it requires extreme muscular force or strength, extreme skilled, and also requires more cardiac efficiency. So, PER in Borg scale [2] is also significantly higher in Jacquard loom weaver.

Comparison of the mean values of working heart rate and the partial recovery heart rate (beat/min) of the two groups has been represented in Fig. 1.

The PREC may be considered as a measure of work stress as well as work strain [15]. The jacquard loom weavers had more PREC values but it is not significant. They recover rate little bit faster but the cardiac parameters in Jaquard loom weaver took more time to come to normal. HRmax declines with increasing age, so assessing cardiovascular indices is decisive in evaluating physiological workload, but studies in real situations are limited. Perceived exertion rating is also high among handloom weavers. According to Maritz et al. [12], the average working

Table 1 Physical characteristics and work experience of the weavers

Parameter	Handloom weavers	Jacquard loom weavers	p value	Significant/not significance
Age (years)	34.77 ± 7.55	35.84 ± 4.94	0.5920	NS
Height (cm)	160.62 ± 4.61	165.95 ± 4.2	0.0003	S
Weight (kg)	62.08 ± 7.05	55.68 ± 5.04	0.0016	S
BMI (kg/m^2)	24.09 ± 2.88	20.29 ± 2.33	0.0001	S
Experience (years)	17.0 ± 7.47	16.1 ± 6.03	0.5403	NS

Values: mean ± SD, *S* significant, *NS* not significant

Table 2 Comparison of cardiac indices parameters

Parameter	Handloom weavers	Jacquard loom weavers	Significant/not significance
Rest HR. (beats/min)	70.92 ± 2.89	69.74 ± 2.4	NS
NCC (beats)	801.56 ± 112.41	1311 ± 211.95	S
RCC (%)	37.19 ± 12.25	41.55 ± 8.78	NS
WHR_{max} (beats/min)	119.28 ± 5.69	144.53 ± 11.53	S
PREC (%)	37.19 ± 12.25	41.55 ± 8.78	NS
%AWHR	45.66 ± 2.91	37.91 ± 5.63	S
%WHRmax	35.58 ± 4.27	35.58 ± 4.27	NS
Energy expenditure (Kcal)	3.95 ± 0.26	5.08 ± 0.51	S
RPE	11.2 ± 1.87	13.4 ± 1.42	S

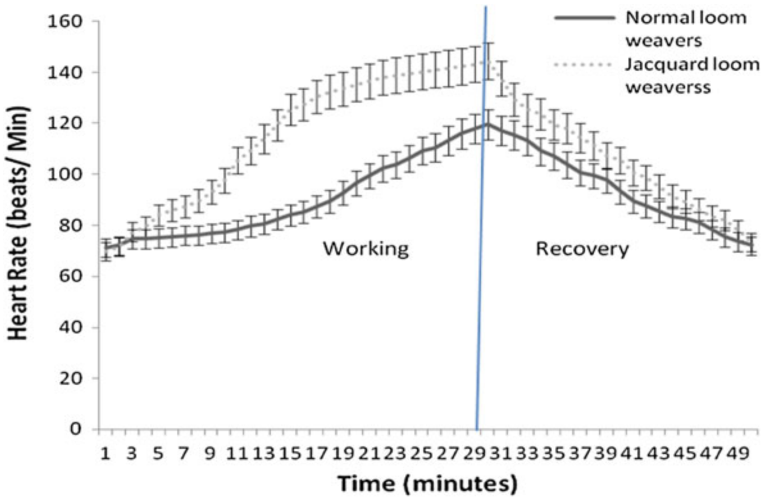

Fig. 1 Comparison of the mean values working heart rate and partial recovery heart rate (beat/min) of the two groups (normal handloom weavers and Jacquard loom weavers). The *horizontal bars* represent standard error of mean (SEM)

heart (AWHR) standard for 8 h industrial jobs should be 105 beats/min with a range of 95–115 beats/min. But as per Brouha [3] HR in the industry should not exceed 110 beats/min as cumulative fatigue would likely to ensue beyond this HR level. Later, Saha et al. [16] proposed that the acceptable workload for sustained physical activity might be considered as 35% of the maximum aerobic power for Indian male workers, which corresponded to working heart rate of 110 beats/min the mean AWHR was found to be 119.28 ± 5.69 and 144.53 ± 11.51 beats/min in the normal handloom weavers and jacquard loom weavers, respectively, and statistically significantly.

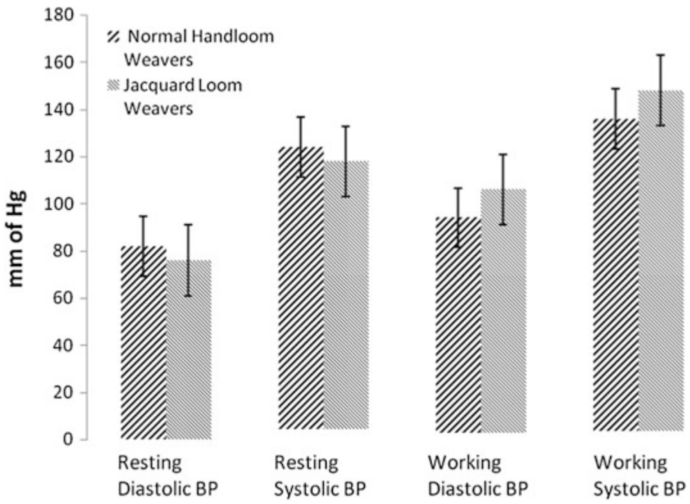

Fig. 2 Resting and working blood pressure of the weavers. The *horizontal bars* represent standard error of mean (SEM)

Handloom industries are filled with different types of strenuous work. In an average they have to work often for 8–10 h of the day to fulfill their work. All the handloom workers are categorized into mainly two types of work according to their handloom types. Due to their different work categories, the level of cardiac strain alters from individual to individual. The cardiac strain parameters such as NCC, RCC, etc. are much higher in the case of the workers who do their working demand. Energy expenditure is significantly higher among jacquard loom weavers than the normal loom weavers.

Resting and working blood pressure comparison was represented in Fig. 2.

It was observed that a large number of weavers have no handloom of their own. Handloom weavers work hard for their livelihood in a very small room with minimum ventilation and low illumination. In Nadia district weaving is a principal form of cottage industry and forms the second major occupation. With advancing age, cardiovascular strength decreases [18] and thus, environmental heat exposures are added additional stress to them [8].

4 Conclusion

As per Indian factory act (1948), it has been recommended that all the adult workers should perform their work not more than 8 h in a day. But in the case of the handloom workers the working hours is much more.

Thus it can be concluded from the study that the cardiac stress is greater among the Jacquard loom weavers than the normal loom weavers and BMI is below. Ergonomic interventions are necessary to reduce the cardiac stress of the jacquard loom weavers.

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Chapter 20
Workspace Amenities for Assam Policewomen: Ergonomic Interventions

Shilpi Bora, Abhirup Chatterjee and Debkumar Chakrabarti

Abstract The present research explores the womanhood issues at workplace with specific reference to the basic amenities in the police station; and we aimed to evaluate the occupational well-being of policewomen. For this, forty three (n = 43) women police personnel of mixed age and ethnicity, deployed at the women police station of Pan bazaar, Guwahati, responded to a bipartite questionnaire, which envisioned their present workplace scenario and issues therein. Descriptive analysis was undertaken to understand the problems tackled by women personnel in the police station. Review of the situation and observations obtained through questionnaires revealed the basic inconveniences of policewomen in terms of lacking basic amenities like conveniences and passable privacy at workplace. Ergonomic interventions were proposed after thorough scrutiny of the situations and possibilities to recover from them, and were thus intended to aid policewomen to lessen their problems hindering their well-being.

Keywords Policewomen · Jobsite amenities · Workplace comfort · Conveniences

1 Introduction

Today's women are essentially participating for men's equivalence outside the family premises—including their contribution to the nation also by the virtue of their entrance into once male-dominating professions such as police forces, which is still to a great extent considered to be one of the most masculinized occupations and

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therefore being recognized with potential and strength. The job of Police personnel is indeed a challenging one, which encompasses uncertainty in many terms including longer hours of duty, sudden unexpected deployments, and exposure to unavoidable risky circumstances, to name a few. In the prevailing sociocultural setup, policewomen are often overstrained and thus, find it difficult to maintain equilibrium between their job and homemaking responsibilities. This advocates some situational concerns about the women in police service like universal gender bias within the police force, the contexts/situations that policewomen are compelled to bear within course of satisfying their job responsibilities, etc.

Police service poses considerable occupational stress largely due to its various undesirable consequences on the individuals and on the organizations (the Service) at large. Workplace problems differ from other stressors in aspects like difficulties in balancing a job with family responsibilities or a person's personality traits and related trends of coping with workplace problems. Workplace problems are troublesome features of any organization. The police service is known to pose workplace problems having considerable influence on stress [10].

With reference to the daily on-job rosters of the policewomen across India, and the same being equally applicable for policewomen of Assam Police, they are commonly witnessed to go through quite a few adversities for example, lesser acceptance of their on-job role to their family, conflicts in balancing job and family components, on-job stress, lack of job satisfaction, workplace discomfort on personal front, and with inadequate welfare measures, unsatisfactory facilities, less flexible leaves and benefits, etc. on the organizational front. To look into the women specific issues related to the police forces of Assam, the present work attempted to scrutinize the status of policewomen in Assam specific to the inconveniences they face in their workplace police station, outposts or patrolling duties, being women, followed by approaching with some ergonomic interventions to minimize the discomfort and related stress.

2 Methodology

The present study, being a research-cum-review in nature, was based on primary data as well as secondary data. Primary data was compiled from survey-based personal interview and individual responses to a bipartite subjective assessment questionnaire. Secondary data was acquired from the office of the Commissioner of Police, journals, newspapers, articles, etc. The questionnaire was administered by 43 women police personnel ($n = 43$, selected by purposive non-probability sampling, after explaining them the purpose of the study and obtaining individual informed consent) of different ranks but posted in Guwahati (All women Police Station of Pan bazaar, Guwahati, Assam). Table 1 shows the questionnaire that was developed for subjective assessment of workplace and on-job amenities.

The design of the study was descriptive in nature, wherein we attempted to assess the psychosocial and occupational concerns, and the stress imparted thereby on the policewomen in their workplace, also extended to their outstation duties like

Table 1 Participant response questionnaire for subjective assessment of workplace and on-job amenities

Part A: Exposure to occupational and environmental stress and perceived well-being	
Please use the following response scale to indicate the extent to which you agree with each statement regarding your job satisfaction. Please choose the scale that is most closely applicable for each statement: (1) strongly agree; (2) agree; (3) neither agree nor disagree; (4) disagree and (5) strongly disagree	
1	Law enforcement is generally regarded as a masculine profile, therefore we who are inducted in this job, felt that convenience is equally important for us
2	Staff shortages cause stress
3	Lack of resources cause stress
4	In equal sharing of work responsibilities cause stress
5	Shift work causes stress for special cases Like pregnancy, expecting mother, lactating mother, menstruation period
6	Traumatic events affects psychophysical health
7	Social life outside the job is impacted by duty regimen
8	Feelings like you are always on the job and other responsibilities are compromised
9	Frequent interruptions brings disturbance in the work place
10	Inadequate or poor quality equipment/maintenance
11	Unfair work environment in this job
12	Lack of a modern system/apparatus on duty
13	Occupational health issues (e.g., back pain, neck pain, joint pain)
14	A good infrastructure brings satisfactions while doing work
15	Lack of resources in professional/promotional
16	Working alone at night is risky and I don’t feel good
17	Prolong standing affects physical health
18	Lack of separate modular convenience/prompt service utilities in every police station
19	Basic amenities like isolated/separate restrooms and child care units are still a major requirement for women police personnel
20	Lack of residential accommodation which is seen as one of the major impediments faced by women in joining police force
21	While I am involved in outdoor activities such as patrolling, security duty on several occasions, touring in and outside the district where mobile convenience facility is a compulsory requirement.
22	Crèches/daycare center in the police station for working mother will help them to take care of their children
Part B: On-job satisfaction	
Please response to the following statements to indicate the extent to which you agree with each statement regarding your job satisfaction. Please choose ‘Yes’ or ‘No’ for each statement	
1	Public attitude toward women police is awkward
2	Lack of separate utility facilities in police stations
3	Problems related to training
4	Govt accommodation for womanhood-related issues
5	Difficulties faced in upbringing of children—daycare center is essential
6	Need to have a better working environment in terms of infrastructure
7	Provision of separate toilet facility at all offices/outpost
8	A modular mobile convenience facility while outdoor duty an immediate need

Fig. 1 Interaction with policewomen

patrolling, etc. Individual interview method (audio recording with individual informed consent) was adapted to collect required information, since responses to the questionnaire alone might not be sufficient to have deeper perception from the respondents about the ground situation. One to one interaction (refer to Fig. 1) facilitates smooth interaction between interviewer and interviewee.

The respondents might perceive questions in their own way. This interview schedule helped us to explain the purpose of survey to the respondents and intend to gather relevant information.

3 Results and Discussion

A thorough scrutiny of the present Indian scenario in the above aspect by review of existing literature on policewomen, government documentations including parliamentary committee reports, and other societal awareness programs has resulted in several constructive suggestions and recommendations regarding in-the-workplace comfort of women working in police forces. The Parliamentary Committee on ‘Empowerment of Women’ documented the working conditions of women in police force (in its 2013–2014 and 2014–2015 reports) referring to the lack of facilities for the women. The Committee articulated that these issues can only be tackled through persistent efforts and constant followup by the government along with time-bound action plans.

The characteristic police duty roster requires elongated working hours, and also involves outdoor activities such as patrolling, duties on several occasions, and touring in different areas with different concerns. The Union Ministry of Home Affairs has emphasized all states to include lockable rest rooms and due privacy for women personnel in every police station "on priority" in their action plans for 2014–2015 by claiming funds from the ministry's scheme of modernization of police forces. At all the existing police stations, outposts, and barracks, a provision must be made for suitable toilet facilities for women personnel including sitting area, adequate privacy, and proper separate bathroom with adequate supply of water. Home ministry have also added [8] the rest room needs to be separated from other parts of the workplace and it should be clean, secure, and located at a convenient place close to the toilet. The room and the toilet should reasonably be accessible to the women police officials so that their security is not compromised. The ministry have also added that the rest room should be big enough to be used as a changing room by the women personnel. Based on a visit (this study) to police stations in Guwahati, basic facilities were found to be in a shocking state of affairs (Fig. 2a, c, e, g). A separate toilet and rest room for women personnel were still at the initial stage, which is a very essential for the specific issues of women in the working area wherever they are not receiving the sufficient facilities, that are given to the other organization.

A vivid interactive interview with policewomen of Women Police Station (Pan Bazar, Guwahati) and the questionnaires they responded to revealed a gross mixed trend of opinions regarding the current scenario in terms of exposure to occupational and environmental stress and perceived well-being, conveniences, and also job satisfaction. Earlier at the time starting of this experiment, the compilation of questionnaire reports revealed a gross dissatisfaction pinpointing some real-time inadequacies pertaining to womanhood issues like basic amenities (Fig. 2a, c, e, g), specific issues related to women, privacy area, proper sitting area, convenience facilities, etc. Focusing on the gross scenario posed a need of ergonomic interventions leading to a healthier work environment. So this study proposed to approach with some ergonomic intervention in the area of basic amenities for occupational well-being like convenience facilities, adequate privacy, etc. to the higher authority, which resulted in development of infrastructure pertaining to convenience/amenities (Fig. 2b, d, f, h). This in turn resulted in betterment of the existing workplace with improved morale and comfortable working condition and reduced stress.

Nowadays, various facets of the policewomen's socio-occupational aspects relevant to work-life balance are secondary in organization such as working nature, late night duties, duty with no regular holidays and work schedule, gender

(a) Women Police Station – then

(b) Women Police Station – now

(c) Rest room was common for all, and inside the prisoners' cell

(d) Modernised rest rooms for police, built outside the prisoners' cell

(e) Office furnitures – then

(f) Office furnitures – now

(g) Office and sitting area – then

(h) Office and sitting area – now

Fig. 2 Ergonomic interventions proposed for workplace improvements of Women Police Station, Pan bazaar, Guwahati, and some of their implementations towards facilitating the workplace environment and basic amenities. The figures depict the conditions prior to (**a**, **c**, **e**, **g**) and after (**b**, **d**, **f**, **h**) ergonomic interventions discrimination, etc. Job satisfactions are some of the serious elements to an organization's effectiveness and competent functionality [7]. There are numerous reasons for women joining the police. Among them, job security, responsibility, respect and recognition, promotion opportunities, and pay are the most common factors. However, most women in the police are not satisfied with their promotion opportunities and working conditions too. Working conditions include inadequate welfare measures, insufficient facilities, uncertain working hours, etc. Thus the policewomen must be provided with certain possible compensatory measures by the way of better conditions of work like flexible working conditions, conveniences, mobile facilities, and amenities.

The survey-based research and review from IIT Guwahati perceived requirement of the basic amenities specific to womanhood like separate sitting area for women with adequate privacy, separate convenience facilities for women, privacy preserved changing spaces, etc. These are the societal need of the hour to be addressed urgently, where ergonomic design interventions were proposed to constitute a more hygienic, user friendly, and amiable workplace, leading to boosted motivation for, satisfaction from, and dedication to the job responsibilities.

4 Conclusion

We perceived and proposed to implement the basic amenities specific to womanhood to offer a better workplace for them, through ergonomic design intervention for more dedication to the job responsibilities, some of which was implemented for Pan Bazar Women Police Station, Guwahati. The study also attempted few probabilities in women police workstation and the occupational design issues for policewomen. These changes were trailed out in consultation with higher authorities of Assam Police and are still in the initial phase. It will thus help policewomen to identify their potential thereby empowering them against various kinds of on-job stress.

The present study writhes from the limitation of the relatively small sample size as the total census of policewomen in Assam Police contributes only to 0.93% of the total force; only 60 policewomen are posted in Guwahati assigned to differential duty rolls.

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Chapter 21
Physiological and Metabolic Status of Bus Drivers

C.K. Pradhan, I. Chakraborty, S. Thakur and S. Mukherjee

Abstract The present study was undertaken to assess their cardiovascular responses, energy expenditure, workload, musculoskeletal pain and discomfort along with blood and urine parameters. One hundred forty one bus drivers of Kolkata participated in the study. Their anthropometric measurements were recorded. Their physical examination was conducted and clinical history was recorded. Subjective assessment of workload, pain and discomfort was also done. Metabolic status of drivers was determined by biochemical analysis of blood and spot urine samples. Heart rate was recorded every minute by Polar Heart Rate Monitor. Their average working heart rate (AWHR), peak working heart rate (PWHR) and energy expenditure (EE) were determined. Mean value of BMI (21.9 ± 3.13 kg/m^2) indicated the bus drivers as 'normal' category; however, there were 26% overweight and 14% underweight subjects. Waist–hip ratio of the subjects indicated that 92% subjects had abdominal obesity. Blood pressure values showed drivers were prehypertensive (52%—systolic, and 50%—diastolic) and hypertensive (18%—systolic and 29%—diastolic). Their health-related complaints indicated chronic stress in the bus drivers. AWHR indicated workload category as moderate. Considering EE of driving a bus, the mean value of 3.86 ± 0.55 kcal/min indicates the workload as light to heavy. Subjective assessment showed workload as extremely heavy (11%), very heavy (39%), heavy (34%) and moderate (16%). Prevalence of musculoskeletal pain and discomfort was reported by 31% bus drivers. Although the workload of bus driving is light to very heavy (physiological) and moderate to extremely heavy (subjective), the factors like type and duration of duty hours, demands of beneficiaries such as passengers and employers, non-availability of proper food and drinking water during working hours, etc. are responsible for causing stress to a bus driver. The presence of abdominal obesity in the majority of the bus drivers as evidenced by waist–hip ratio indicates

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defect in energy metabolism in this group. Biochemical parameters indicate that they are prone to increase cardiovascular risk and at the risk of development of atherosclerosis.

Keywords Bus driver · BMI · Waist–hip ratio · Heart rate · Energy expenditure · Glucose · Triglyceride · Homocysteine

1 Introduction

In Kolkata about 11.64 lakh vehicles ply. There are about 12,341 stage and 39,065 contract carriages [8], and the number of buses is increasing. The bus drivers have long and irregular duty hours of 12–15 h daily. They are compelled to take unhealthy and unhygienic food and water.

Earlier reports suggested that the work stress of the drivers is heavy [1, 14]. Bus driving is an example of high-strain occupation, with high risks of physical and mental health, leading to absenteeism [9]. Traffic congestion is another stressor. Stress is believed to play a significant role in causing certain physical (cardiovascular disease, gastrointestinal disorders, musculoskeletal problems, fatigue), psychological (depression, anxiety, post-traumatic stress disorder) and behavioural outcomes [20].

Though various occupational disorders of the transport workers have been reported, studies on physiological and metabolic status of the bus drivers are scanty. The present study was carried out with the following objectives.

1. To assess acute and chronic morbidity pattern among bus drivers.
2. To assess their nutritional status, workload and energy expenditure during work.
3. To assess their physiological and metabolic status (cardiovascular responses, pulmonary function, and blood and urine biochemistry.

2 Materials and Methods

Lists of bus drivers (age 21–40 years) were collected from different bus terminuses. From the list, 141 bus drivers participated in the study. Nutritional status of the subjects was assessed from their body mass index (BMI). Their body composition, i.e. body fat percentage and lean body mass, were assessed [7, 18] from their body weight and skinfold thickness at different sites (biceps, triceps, subscapula and suprailiac) of body using a skinfold calliper (Holtain, UK). They were interviewed for subjective assessment of workload, pain and discomfort.

Pulmonary function values were recorded by the Spirovit-Sp-10 (Schiller Health Care Pvt. Ltd, Switzerland) and Peak Expiratory Flow Rates (PEFR) by Wright's Peak Flow Meter (Clement and Clarke UK).

Metabolic status of drivers was determined by biochemical analysis of blood and spot urine samples. Blood Haemoglobin, plasma glucose (fasting), serum total protein, albumin, triglyceride, cholesterol, HDL and LDL cholesterol, homocysteine, serum urea and creatinine, and liver enzymes levels like Aspartate Transaminase (AST), Alanine Transaminase (ALT) and Gamma Glutamyl Transpeptidase (GGT) were analysed. Urine samples were also collected for determination of urinary protein creatinine ratio [2].

Physiological assessment of workload was carried out from heart rate and energy expenditure [15]. Heart rate was recorded continuously during driving using a heart rate monitor (Polar Accurex Plus, Finland). Average working heart rate (AWHR), peak working heart rate (PWHR) and net cardiac cost (NCC) during the work period of 1 h were determined. The energy cost, i.e. energy expenditure (EE) of driving, was determined from the recorded heart rate and the average energy cost was calculated [6]. The subjects were interviewed to obtain basic information and were assessed for subjective workload [16] on a scale of 1–5 (light, moderate, heavy, very heavy and extremely heavy). They were asked to point out the part(s) of the body where they feel work-related musculoskeletal pain or discomfort [5].

3 Results

Experience of subjects varied from 3 to 25 years with a mean of 10.1 ± 5.35 years. Physical characteristics of the bus drivers are presented in Table 1. Body height, weight and body surface area were comparable with normal Indian population [3]. Mean value of BMI indicated the bus drivers as 'normal' category. There were overweight (26%) and underweight (14%) subjects. Waist–hip ratio (WHR) of the subjects indicated that 92% subjects had abdominal obesity [21].

Table 1 Physical characteristics of bus drivers (n = 141)

Parameters	Mean ± SD
Age (years)	34 ± 5.01
Body height (cm)	164.8 ± 5.7
Weight (kg)	61.1 ± 10.2
BMI (kg/m^2)	22.5 ± 3.47
Fat (%)	18 ± 4.9
Lean body mass (kg)	49.7 ± 6.36
Waist–hip ratio	0.99 ± 0.08

3.1 Health Survey

With reference to past history of illness, morbidity pattern of the bus drivers showed that they suffered from jaundice (42%), skin disease (24%), malaria (18%), respiratory disease (7%) and tuberculosis (6%).

The subjects were habituated with different types of addictive materials like smoking beedi and cigarette (71%), drinking alcohol (55%), chewing tobacco (36%), chewing gutkha (17%) and inhaling ganja (4%). Present health-related complaints as reported by the bus drivers were as follows—increased frequency of micturition (16%), nocturia (13%), fatigue (21%), weakness (24%), sleep disorders (12%), etc. As a whole, an indication towards chronic stress was found.

The mean systolic and diastolic blood pressures are 124 ± 14.5 and $84 + 10.3$ mm of Hg, respectively. The individual values showed some of the bus drivers were prehypertensive (systolic—52%, and diastolic—50%) and hypertensive (systolic—18% and diastolic—29%). Clinically, no abnormal finding was noted on examination of cardiovascular and nervous system.

3.2 Respiratory Physiology

Results of pulmonary function test showed their lung volumes and the flow rates were within the normal range [4]. However, four bus drivers (2.8%) had obstructive impairment, two (1.4%) had combined impairment and one (0.7%) had restrictive impairment.

3.3 Physiological Study

The mean value of resting heart rate of the subjects was 77 ± 6.8 (beats/min). The workload was classified according to Sen and Nag [15]. The AWHR was 100 ± 13.9 (beats/min) indicating workload category as "moderate". However, the PWHR of the drivers ranged from 91 to 153 with an average of 117 ± 12.3. Considering EE of driving a bus, the values varied from 2.68 to 5.47 kcal/min with the mean value of 3.86 ± 0.55 kcal/min, indicating that the workload was light to heavy. The average value of NCC (beats) for 1 h is 1163 ± 555.2.

According to subjective assessment, workers reported the workload as extremely heavy (11%), very heavy (39%), heavy (33%) and moderate (16%). The feeling of 'extremely heavy' is probably due to long working hours.

Prevalence of musculoskeletal pain and discomfort was reported by 31% of the bus drivers. The most affected body part was lower back (21%), followed by knees (9%), calf (5%) and neck (4%). Some of the drivers (19%) reported that they had met accidents during their work.

Table 2 Level of different biochemical parameters of bus drivers (n = 141)

Parameters	Mean ± SD	Median value	Reference interval	% value > reference interval	95% confidence interval
Blood					
Glucose fasting (mg/dl)	93.13 ± 18.96	90.00	74–100	18	90–96
Total protein (gm/dl)	7.54 ± 1.04	7.71	6.40–8.3	18	7.4–7.7
Albumin (gm/dl)	4.58 ± 0.63	4.60	3.5–5.2	11	4.5–4.7
Triglyceride (mg/dl)	142.63 ± 68.42	122.00	<150	36	132–156
Cholesterol (mg/dl)	154.82 ± 45.99	151.00	<200	13	147–162
HDLc (mg/dl)	44.73 ± 8.44	44.00	30–70	0	43.4–46.2
LDLc (mg/dl)	81.25 ± 44.82	77.20	<100	28	73.8–88.60
Homocysteine (µmol/l)	11.14 ± 6.06	11.90	<15	10	10.2–12.2
Urea (mg/dl)	25.64 ± 9.99	23.00	20–40	9	24–27
Creatinine (mg/dl)	0.99 ± 0.27	0.92	0.07–1.2	23	0.95–1.04
ALT (IU/l)	36.19 ± 34.86	24.00	<45	22	30.4–41.9
AST (IU/l)	34.74 ± 38.30	22.30	<37	26	28.6–41.2
GGT (IU/l)	41.39 ± 28.33	35.00	8–61	20	35–59
Urine					
Protein creatinine ratio	0.15 ± 0.15	0.10	<0.30	12	0.12–0.17

3.4 *Biochemistry*

The result of biochemical analysis has been presented in Table 2, showing mean, median and 95% confidence interval values.

In case of GGT, an indicator of liver function and chronic alcohol abuse, 20% bus drivers had GGT values more than the upper reference limit, i.e. 61 IU/l. This is most likely due to chronic abuse of alcohol. Actually, 65% subjects were current users of alcohol and out of them 51% of the users were used to take alcohol more than 3 times a week.

None of the bus drivers were anaemic.

4 Discussion

In the present study, 18% bus drivers reported that they had suffered from malaria. As the bus drivers have to stay many a time within bus itself during night, they are also prone to vector-borne disease like malaria. Waist–hip ratio showed that majority of subjects (92%) had abdominal obesity, indicating that the bus drivers were at risk of developing non-alcoholic fatty liver disease [22].

Some of the bus drivers were prehypertensive and hypertensive, as earlier reported by Lakshman et al. [10] that bus drivers were prehypertensive (41.9%) and hypertensive (41.3%). The prehypertension range of the bus drivers of present study was more than the prevalence of prehypertension in the population residing in

Kolkata [17]. These indicated that they suffer from chronic stress and are prone to increase cardiovascular risk.

Workload of the bus drivers was in the "moderate" category. This has been reflected in both subjective and objective assessments of the workers. It is essential to take into account the perception of the subjects when one attempts to evaluate the difficulty associated with work [13].

Musculskeletal pain and discomfort were prevalent among 31% bus drivers. The most affected body part was lower back, knees, calf and neck. These findings corroborate with earlier studies such as Szeto and Lam [19] and Okunribido et al. [12]. Leinonen et al. [11] reported that the postures adopted by the drivers and conductors create stress on their musculoskeletal system especially in the back and leg, causing pain and discomfort.

5 Conclusion

Although the workload of bus driving is moderate (physiological) and moderate to extremely heavy (subjective), the factors like type and duration of duty hours, demands of passengers and employers, non-availability of proper food and drinking water during working hours, etc. are responsible for causing stress to a bus driver. The presence of abdominal obesity in the majority of the bus drivers as evidenced by waist–hip ratio indicated a defect in energy metabolism in this group. Biochemical parameters indicated that they are prone to increase cardiovascular risk and at the risk of development of atherosclerosis.

The result of the study will be beneficial for the bus drivers as they would be made aware of the hazards. They could be guided for taking care of their health by improvising their lifestyle, food habit and work practice. All the bus drivers should be screened at pre-employment stage and periodically during their job period to detect and prevent deterioration of their morbidity status.

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Chapter 22
Effectiveness of a Participatory Ergonomics Intervention to Improve Musculoskeletal Health: A Solomon Four-Group Study Among Manufacturing Industry Workers in Selangor, Malaysia

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Abstract The aim of this Solomon four-group study was to evaluate the effectiveness of participatory ergonomics (PE) intervention to improve musculoskeletal health among manufacturing industry workers. A total of 436 workers were randomly assigned into four groups. Intervention groups went through PE intervention while control groups went through hearing conservation programme. The main outcome measures were the prevalence and intensity of musculoskeletal pain at 9 body sites, collected by questionnaires at baseline (pretested groups) and 3 months after PE intervention (all groups). The study found that lower back has the highest prevalence rate of musculoskeletal disorders (MSD). There was significant lower prevalence rate of MSD at upper back, lower back and knee for intervention group as compared to control group. There was a significant main effect of PE intervention on the overall pain intensity at different body parts whether they are pretested or non-pretested. In conclusion, PE intervention had effectively improved musculoskeletal health among the respondents.

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1 Introduction

Work-related MSD are consistently one of the most commonly reported occupational health problem, bringing enormous pervasive impacts to the society in both direct costs due to the medical healthcare consumption and indirect costs through loss of work productivity [1, 2]. In Malaysia, MSD cases reported to the Social Security Organization (SOCSO) has increased tremendously from 10 (2005) to 675 (2014) cases [3]. Given that MSD has been closely linked with physical and psychological factors at work such as poorly design workstation, inappropriate work method, and stressful environment, etc., there is an obvious need of effective ergonomics intervention targeting at workplace improvement.

PE intervention is a promising strategy to reduce MSD [4, 5]. It is defined as the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals [6]. This study is the first, to our knowledge that evaluates the effectiveness of PE intervention to improve musculoskeletal health among manufacturing industry worker using Solomon four-group design.

2 Method

The study commenced from January 2014 (enrolment) to April 2015 (posttest).

2.1 Study Design and Study Population

This Solomon four-group study was conducted at 9 manufacturing companies in Selangor. Selangor state was selected as the study location because Selangor has the highest number of manufacturing companies registered in Malaysia and the highest number of MSD cases reported to SOCSO [3]. The full CONSORT diagram is shown in Fig. 1. Among 456 workers, 436 were enrolled, 20 declined or not meeting eligibility of study: ≥ 18 years old, work at present company ≥ 3 months, not pregnant, no history of MSD due to nonwork-related factor. 436 workers were randomized into 4 groups: pretested control group, pretested intervention group, non-pretested control group and non-pretested intervention group. Out of 436 participants, only 324 of them completed all parts of the study, with 112 of them loss to follow up due to turnover (loss to follow up rate = 25.7%).

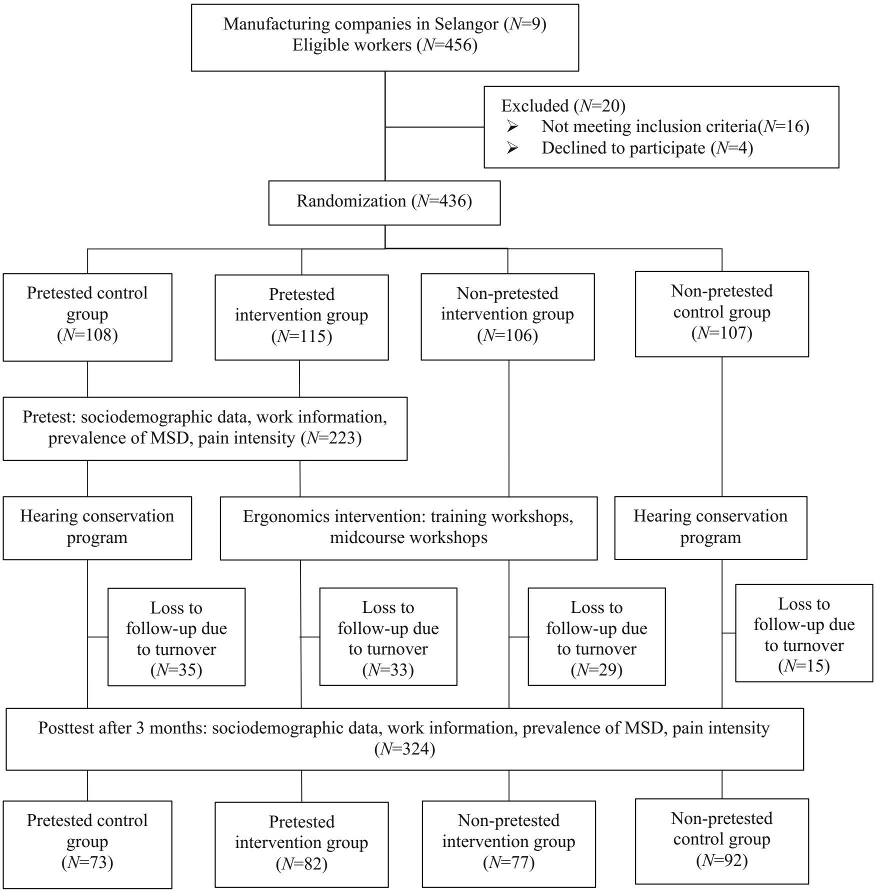

Fig. 1 CONSORT flow diagram

2.2 *Intervention Programme and Control*

The intervention programme in this study was designed based on the Participatory Ergonomics Framework (PEF) by Haines et al. [6]. The programme involved direct representative participation of workers from wide range of work positions to improve their current workstations on voluntarily basis. The core element of PE intervention was the active involvement and discussion among participants to identify, plan, implement and decide the improvements on current workstations, tools, equipment or work tasks in collaboration with management and researcher. The researcher acted as trainer and facilitator to provide ergonomics training, guide and assist the whole PE intervention programme. Overall, the PE intervention programme could be divided into 3 phases: preliminary walkthrough survey, Tailor-made Ergonomics training (8 h) and Follow up with mid-course workshops.

Preliminary walkthrough survey was a very important phase to know the process and work activities of the company in detail. During walkthrough survey, photographs and videos of ergonomics risk factors, good points and potential improvements were taken to be used as training materials for ergonomics training and as baseline information for comparison after PE intervention.

Ergonomics training was the key element of PE intervention. All the trainings were tailor-made according to the information collected during preliminary walkthrough survey. Generally, the topics covered in the training included workstation design, work posture, work method, lifting technique, etc. The action-oriented ergonomics training in this study adapted suggestions and constructive ideas from work improvement in small enterprises (WISE) project [7, 8], which emphasized on practical ideas rather than general theory. In the first session of training, participants were taught to identify risk factors and hazards with the mechanism of injury, followed by practical and potential improvements by using local good examples from all the participating companies. The training involved a lot of discussion and group works with participants. In the second session of training, the participants were divided into groups (6–8 person per group) according to their production line. They were asked to identify strenuous tasks and risk factors at their workstations. Through group discussion, they prioritized top three risk factors identified and subsequently brainstormed about the potential improvements that could be done. All the ideas and decisions were generated through group discussion facilitated by researcher and were written in an action plan. Participants were given 6 months to implement changes and improvements as in the action plan.

During these 6 months, the researcher contacted with the safety and health personnel of the company to follow up on the progression of the action plan every month. All the changes were implemented voluntarily using company fund. Optional mid-course workshops were conducted on request to give supports on improvement. The researcher facilitates the workstation improvement by providing technical advices and feasible suggestions. Participants in the control group were given hearing conservation programme, which includes hearing test and training on hearing protection devices usage.

2.3 Data Collection and Outcome Measures

Data were collected before intervention (pretest) among pretested intervention and control group (N = 223) and after intervention (posttest) among all the respondents (N = 324) using self-administered questionnaire. The primary outcome measure was the prevalence and pain intensity of MSD using modified Nordic Questionnaire [9]. MSD were measured on 9 anatomical sites: neck, shoulders, upper back, lower back, elbows, hands, thighs, knees and foot. The respondents were asked if they experienced musculoskeletal pain on any of the sites within the past 3 months with the aid of illustrations on body sites and marked on a 10 cm Visual Analogue Scale for pain intensity on painful sites. Socio-demographic data and work information were also included in the questionnaire.

3 Results

Table 1 summarizes the characteristics of respondents in the socio-demographic and work information with the prevalence and pain intensity of MSD at 9 anatomical sites as reported in the posttest ($N = 324$). Significant differences between intervention and control group were observed for age, $t(322) = 5.18, p < 0.05$, gender, $x^2(1) = 59.59$,

Table 1 Socio-demographic and work information of respondents with the prevalence of MSD (posttest data; $N = 324$)

Variable(s)	Control group (N = 165)		Intervention group (N = 159)	
	N (%)	M (SD)	N (%)	M (SD)
Age* (years)		34.9 (8.2)		30.4 (7.6)
*Gender**				
Male	147 (89.1)		79 (49.7)	
Female	18 (10.9)		80 (50.3)	
Highest education level				
Primary	3 (1.8)		2 (1.3)	
Secondary	140 (84.8)		109 (68.6)	
Diploma	19 (11.5)		30 (18.9)	
Degree	3 (1.8)		18 (11.3)	
BMI (kg/m^2)		24.8 (4.8)		24.2 (3.5)
*BMI categories**				
Underweight	10 (6.1)		6 (3.8)	
Normal weight	87 (52.7)		103 (64.8)	
Overweight	40 (24.2)		37 (23.3)	
Obesity	28 (17.0)		13 (8.2)	
Monthly income (RM)				
$\leq$ 1500	94 (57.0)		93 (58.5)	
1501–3000	58 (35.2)		58 (36.5)	
>3000	13 (7.9)		8 (5.0)	
*Work position**				
Operator	65 (39.4)		94 (59.1)	
Supervisor	34 (20.6)		23 (14.5)	
Executive	17 (10.3)		9 (5.7)	
Others	49 (29.7)		33 (20.8)	
Work duration weekly (h)*				
<35	10 (6.1)		10 (6.3)	
35–40	36 (21.8)		35 (22.0)	
41–48	45 (27.3)		71 (44.7)	
>48	74 (44.8)		43 (27.0)	

(continued)

Table 1 (continued)

Variable(s)	Control group (N = 165)		Intervention group (N = 159)	
	N (%)	M (SD)	N (%)	M (SD)
Prevalence of MSD at 9 anatomical sites				
Neck	69 (41.8)		55 (34.6)	
Shoulder	73 (44.2)		56 (35.2)	
Upper back*	96 (58.2)		70 (44.0)	
Elbow	38 (23.0)		15 (15.7)	
Hand	54 (32.7)		36 (22.6)	
Lower back*	105 (63.6)		74 (46.5)	
Thigh	41 (24.8)		23 (14.5)	
Knee*	57 (34.5)		30 (18.9)	
Foot	75 (45.5)		58 (36.5)	
Overall prevalence of MSD (at least 1 pain site)	125 (75.8)		120 (75.5)	
Pain intensity at 9 anatomical sites				
Neck		2.7 (2.6)		2.4 (2.0)
Shoulder		2.8 (2.5)		2.4 (2.0)
Upper back*		3.7 (2.9)		3.0 (2.4)
Elbow		1.6 (2.1)		1.5 (1.7)
Hand*		2.2 (2.5)		2.0 (2.1)
Lower back*		4.2 (3.0)		3.1 (2.5)
Thigh*		1.9 (2.3)		1.5 (2.0)
Knee*		2.5 (2.6)		1.6 (2.1)
Foot		3.2 (3.1)		2.6 (2.7)

*$p < 0.05$

$p < 0.05$, BMI categories, $x^2(1) = 7.84$, $p < 0.05$, work position, $x^2(3) = 12.89$, $p < 0.05$ and weekly work duration $x^2(3) = 13.95$, $p < 0.05$.

3.1 Prevalence and Pain Intensity of MSD

The overall prevalence rate of MSD (≥ 1 pain site) was 75.8% for control group and 75.5% for intervention group. Highest prevalence rate of MSD was reported at lower back, followed by upper back and foot for both groups. There were significant lower prevalence rates of MSD at upper back, $x^2(1) = 6.50$, $p < 0.05$, lower back, $x^2(1) = 10.31$, $p < 0.05$ and knee, $x^2(1) = 10.13$, $p < 0.05$ for intervention group as compared to control group. Highest pain intensity was observed at lower back, followed by upper back and foot. Intervention group shows significant lower pain intensity compared to control group at upper back $t(322) = 2.52$, $p < 0.05$, lower back $t(322) = 3.76$, $p < 0.05$, and knee $t(322) = 1.65$, $p < 0.05$.

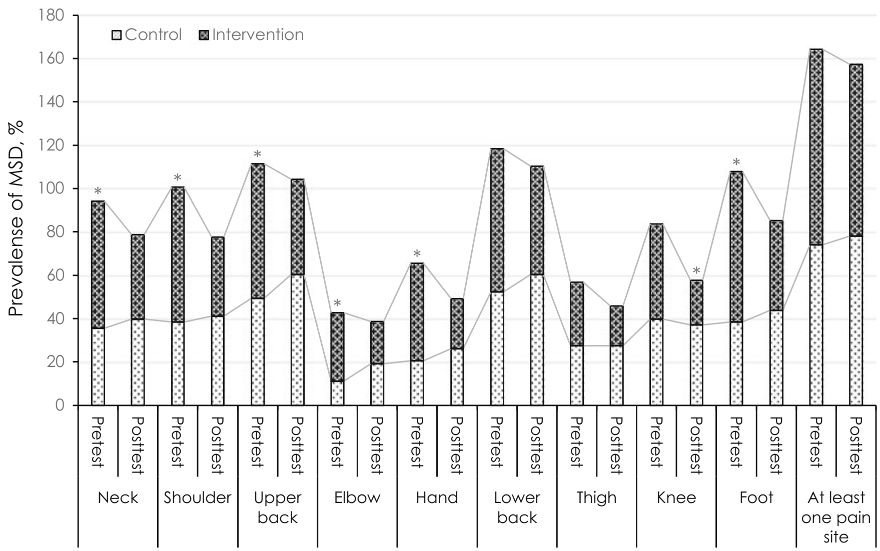

Fig. 2 Prevalence of MSD at 9 anatomical sites for pretested intervention group (N = 82) and pretested control group (N = 73)

As shown in Fig. 2, intervention group shows a clear pattern of reduction in the prevalence of MSD at posttest. At pretest level, intervention group shows significantly higher overall prevalence rate of MSD, specifically at neck, shoulder, upper back, elbow and hand. At posttest level, intervention group reported significantly lower prevalence rate of MSD at knee.

3.2 Effects of Pretesting and Intervention

The effects of pretesting and intervention on musculoskeletal health were examined using conditional sequence of successive analyses for Solomon four-group suggested by Braver and Braver [10]. Pain intensities at 9 anatomical sites were the dependent variables. First, a 2 (pretested × non-pretested) × 2 (intervention × control) multivariate analysis of variance (MANOVA) was conducted on the dependent variables to know the main effect of intervention on overall pain intensity. The Wilks' Lambda test revealed significant main effect of intervention, Wilk's $\Lambda = 0.94$, $F(1{,}320) = 2.36$, $p < 0.05$, no significant main effect of pretesting, Wilk's $\Lambda = 0.54$, $F(1{,}320) = 0.54$, $p > 0.05$ and no significant main effect of interaction (pretesting × intervention), Wilk's $\Lambda = 0.94$, $F(1{,}320) = 0.1$, $p > 0.05$ on the overall pain intensity. The intervention had a significant effect on pain intensity of respondents whether they are pretested or non-pretested.

The results of the univariate ANOVAs as reported in Table 2 show that there were significant main effects of intervention on pain intensity at 3 anatomical sites,

Table 2 Effects of participatory ergonomics intervention on pain intensity at 9 anatomical sites (posttest data; $N = 324$)

Variable(s)	Two-way ANOVA			ANCOVA[a]	Independent samples t test[b]	Meta-analysis[c]	Conclusion
	Pretest	Intervention	Pretest × intervention	Intervention			
Neck	$F(1,320) = 0.08$	$F(1,320) = 1.46$	$F(1,320) = 0.19$	$F(1,152) = 5.64$*	–	–	Effective
Shoulder	$F(1,320) = 0.25$	$F(1,320) = 2.20$	$F(1,320) = 1.02$	$F(1,152) = 1.73$	$t = 1.81$	$Z_{meta} = 2.19$*	Effective
Upper back	$F(1,320) = 0.42$	$F(1,320) = 6.02$*	$F(1,320) = 0.01$	–	–	–	Effective
Elbow	$F(1,320) = 1.44$	$F(1,320) = 0.39$	$F(1,320) = 1.01$	$F(1,152) = 2.61$	$t = 1.18$	$Z_{meta} = 1.97$*	Effective
Hand	$F(1,320) = 1.49$	$F(1,320) = 0.21$	$F(1,320) = 1.37$	$F(1,152) = 1.12$	$t = 1.10$	$Z_{meta} = 1.54$	Not effective
Lower back	$F(1,320) = 0.86$	$F(1,320) = 13.31$*	$F(1,320) = 0.48$	–	–	–	Effective
Thigh	$F(1,320) = 0.02$	$F(1,320) = 2.78$	$F(1,320) = 0.21$	$F(1,152) = 3.34$	$t = 0.93$	$Z_{meta} = 1.94$	Not effective
Knee	$F(1,320) = 0.01$	$F(1,320) = 9.86$*	$F(1,320) = 0.02$	–	–	–	Effective
Foot	$F(1,320) = 0.01$	$F(1,320) = 3.01$	$F(1,320) = 2.72$	$F(1,152) = 10.93$*	–	–	Effective

*$p < 0.05$

[a]Pain intensity reported at pretest used as covariates which only involved pretested intervention and control group ($N = 155$)

[b]Pain intensity reported at posttest as dependent variables which only involved non-pretested intervention and control group ($N = 169$)

[c]Stouffer's z-method combined z-score from previous 2 tests (ANCOVA and independent samples t test)

upper back, $F(1,320) = 6.02$, $p < 0.05$, lower back $F(1,320) = 13.31$, $p < 0.05$, and knee, $F(1,320) = 9.86$, $p < 0.05$. Further analysis shows that intervention group experienced lower pain intensity at upper back (*M* difference = 0.73), lower back (*M* difference = 1.13) and knee (*M* difference = 0.84) as compared to control group.

Since there were no significant main effects of intervention and interaction on the other anatomical sites, the next step in the sequential analysis was to conduct analysis of covariance (ANCOVA) on posttest pain intensity at other anatomical sites among pretested respondents using pretest pain intensity as covariates. The ANCOVA found significant effect of intervention on the pain intensity at neck, $F(1,152) = 5.64$, $p < 0.05$ and foot, $F(1,152) = 10.93$, $p < 0.05$. The pain intensity for intervention group reduced significantly at neck (*M* difference = 0.82) and foot (*M* difference = 1.35). The next sequential analysis involved the testing of intervention effect on non-pretested group using independence t test at the rest of the anatomical sites which were not significant in ANCOVA. Independence t test found no significant effect of intervention ($p > 0.05$) on non-pretested group.

The final step in the sequential analysis was to combine the results from 2 negative tests of intervention effect on pretested and non-pretested group using meta-analytic approach. Using Stouffer's z-method, the p value from previous tests was converted into z-score and combined into a single z_{meta} value. The meta-analytic results were significant for shoulder ($z_{\text{meta}} = 2.19$, $p < 0.05$) and elbow ($z_{\text{meta}} = 1.97$, $p < 0.05$), leading to the conclusion that intervention had reduced the pain intensity of shoulder and elbow.

4 Discussion

In this study, we found that the overall prevalence of MSD among participants for the last 3 months is very high (>70%), consistent with other studies done among manufacturing workers in Malaysia [11, 12]. Lower back was found to have the highest prevalence rate of MSD, similar with studies locally and globally [13, 14].

A systematic review concluded that PE interventions have a positive impact on musculoskeletal symptoms [5]. Our principal finding was consistent with the review, suggesting that PE intervention was effective in improving musculoskeletal health of respondents by reducing the overall pain intensity at different body parts. There are several possible explanations for the effective intervention. The first explanation is the involvement of workers from different positions such as operators, leaders, supervisors and executives. A systematic review suggested that workers, supervisors and specialists or advisors represent the right mix of skills or knowledge to progress through the PE process [15]. Second, tailor-made ergonomics training could have played a significant role. As different work process or job nature would have different ergonomics risk factors, it is important to have the training tailored to suit the task and work environment for different work population. Tailored interventions were found to be more effective in promoting behaviour change and reducing self-reported musculoskeletal discomfort [1]. Another explanation would be the focus on low-cost improvements. According to Kogi [4], PE interventions that focus on low-cost solutions are proven effective for improving workplace.

Sequential analyses further concluded that PE intervention was effective in reducing pain intensity at all anatomical sites except for knee and hand. Pain intensity of knee slightly missed the margin of significance but not pain intensity of hand. We found that it might be due to unchanged workload [16]. As most of the improvements targeted at workstation modification, repetitive movement of hands is unavoidable as long as workload maintained. One of the strengths of our study was the use of Solomon four-group design. In addition to high internal validity for testing the effects of intervention, it has the ability to assess whether the effects of intervention are different among pretested and non-pretested subjects, thus increasing the external validity and generalizability of the study [17]. This phenomenon is called pretest sensitization, where the experimental results may partly be a result of the sensitization to the content of the treatment when pretest is administered [18].

5 Conclusion

The results of current study showed that PE intervention had effectively reduced the overall prevalence rate and intensity of musculoskeletal pain among manufacturing industry workers in Selangor, Malaysia.

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Ethical Approval Research Ethics Committee of UPM approved the protocol.

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Part V
Design Ergonomics

Chapter 23
Ergonomic Intervention for Manual Harvesting in Agriculture: A Review

R. Jain, M.L. Meena and G.S. Dangayach

Abstract The scientific literature regarding prevention of musculoskeletal disorders (MSDs) and other occupational health risks in agriculture have recognized in various studies. A narrative type of review was done for summarizing the content according to the research questions developed. Articles were collected from the seven online article providers. The results show that most of the works were done in developed countries. Also MSD-specific problems (for particular body regions) and performance-related issues are considered in fewer articles. Therefore, there is a need to make research strategies that help to develop and analyze the new interventions for manual harvesting in least developing and newly industrialized countries.

Keywords Agriculture · Ergonomics · Intervention · Manual harvesting · Research question

1 Introduction

Agriculture is more prone to occupational hazards and risks due to less technical development presently. Agricultural research [37] plays a significant role in raising agricultural productivity. There is a huge amount of literature available in agricultural research for musculoskeletal disorders (MSDs) [1, 40, 22] and technology in productivity growth [21, 27]. If numbers of accidents are examined agriculture ranks among three most hazardous sectors [53].

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Several reviews in Agriculture published which are distributed as ‘ergonomic intervention in agriculture’ [9, 19, 28, 36, 50] and ‘status of safety, production at agriculture farms in developing countries’ [44, 45, 48]. Prior to attempting this review for the role of ergonomic interventions in agriculture, three systematic reviews [9, 19, 36] were identified as a base. These reviews [9, 19, 36] concluded that some ergonomic design initiatives must be taken for improving knowledge, attitudes and behaviors toward the farm safety.

2 Methods

2.1 Search Strategy

A selection of the sample of studies to follow three steps are shown in Fig. 1.

2.1.1 Step 1: Search

In the first step, the online databases of 7 publishers were searched using seven different search terms related to MSD interventions put into various combinations. The search terms are agriculture, ergonomics, hand tool, industrial design, intervention, musculoskeletal disorders, and occupational health.

2.1.2 Step 2: Criteria 1

In the second step, the title of all 2809 articles were checked for empirical intervention in the agricultural environment.

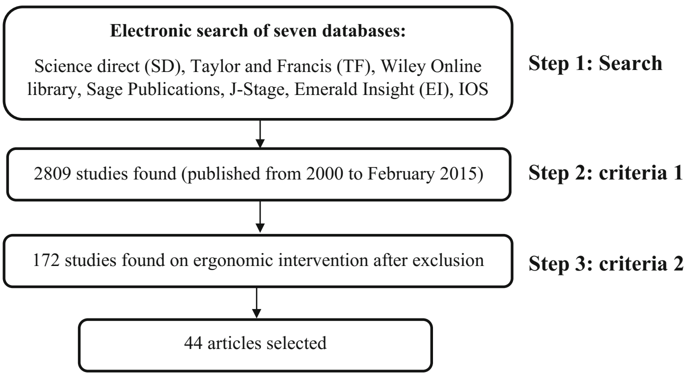

Fig. 1 Overview of selection and inclusion criteria

2.1.3 Step 3: Criteria 2

In the third step, the article must report at least one objectively quantified outcome (MSDs prevention, injury rate, safety knowledge, improves design and productivity, etc.) in the real farm environment.

2.2 Research Questions

Some of the research question was used for categorizing the articles. These questions are as follows:

(a) Keyword related to ergonomics, (b) country- and crop-wise distribution, (c) targeted problem for developing intervention, and (d) intervention tools used.

3 Results

3.1 Research Distribution

Forty-four articles [2–8, 10–18, 24–26, 29, 30, 32–35, 38, 39, 41, 42, 43, 46, 47, 49, 51, 52, 54–62] were selected for categorization. The distribution covers several scientific disciplines, including MSDs, occupational health and safety risks, industrial design, ergonomics, and hand tool design. Huge number of articles focused on hand tool design and education programs for improvement in the farm environment.

Figure 2 shows that maximum studies lie in the three keywords industrial design, intervention development & evaluation, and farm health and safety.

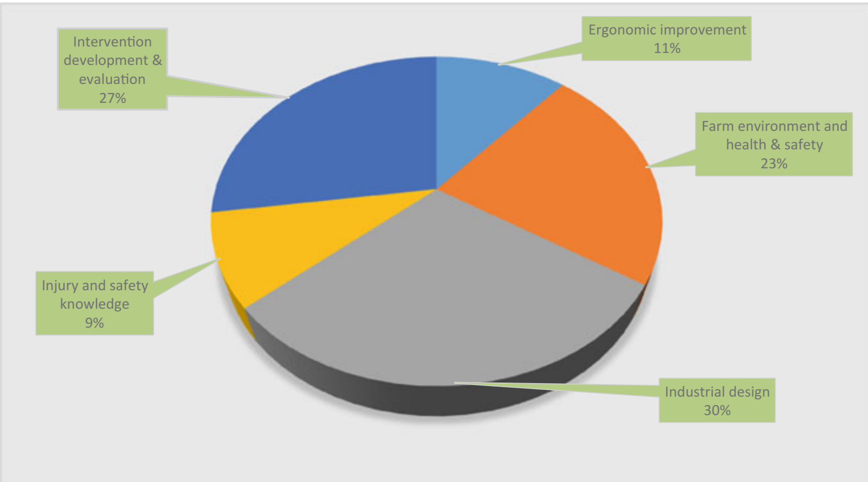

Fig. 2 Keyword distribution

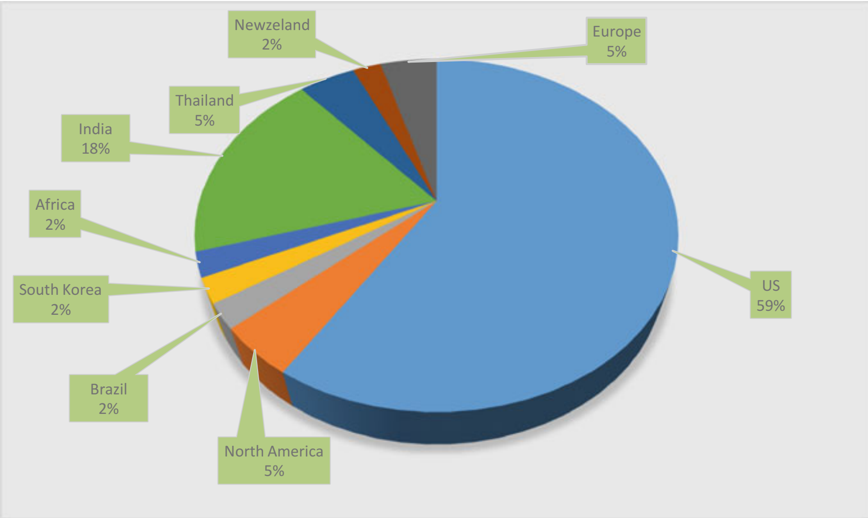

Fig. 3 Country-wise distribution

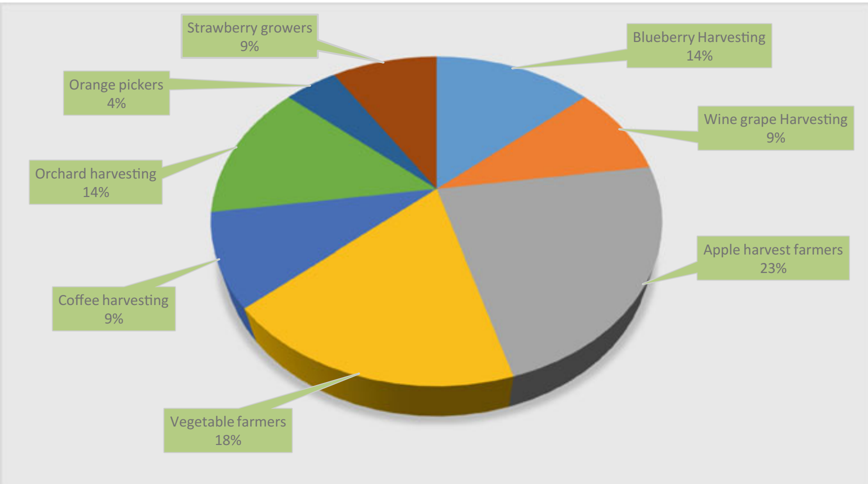

Fig. 4 Crop-wise distribution

Country-wise and crop-wise distribution of the studies also carried out which is shown in Figs. 3 and 4. The maximum study is found in the US, so there is the need for such studies to be done in the developing countries (DC) like Africa, India, some more Asian countries, etc.

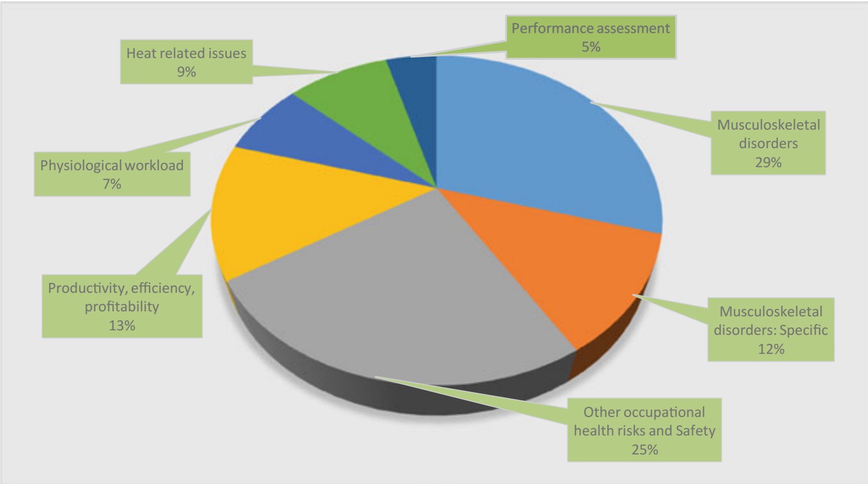

Fig. 5 Targeted problem distribution

Figure 4 shows the crop-wise distribution, and out of 44 studies only twenty discussed the particular crop.

3.2 *Targeted Risks in Agriculture*

Many researchers and organizations (ILO, World Bank, NIOSH, etc.) claim that agriculture farmers have various problems related to MSDs and other occupational health risks.

The selected studies used for solving various problems are presented in Fig. 5 which closely related to the MSDs and other occupational risks associated with the farmers.

This literature covers descriptions of various methods and tools developed in the farm environment. Figure 6 classifies using general approach used in the study as the design, educational training, and some other type of improvements like the new system, some simulation studies, wage and incentive studies, etc. Key elements found for successful approaches must be low-cost solutions [31].

4 Discussion and Conclusions

For the future research, two priorities can be raised for critical comments of the reviewed studies. At first, for the improvement of the quality of research, these elements are necessary: use of existing knowledge for design and development, use

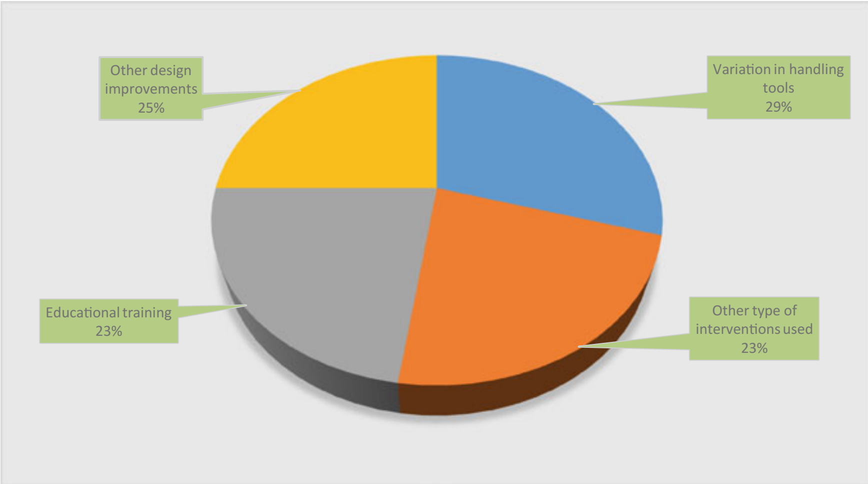

Fig. 6 Intervention tool used

developed studies for a particular activity or on-farm environment, and effectiveness of study for prevention of various problems should be checked properly.

Second, it was important to develop such strategy for effectiveness research, so that complete intervention system can be evaluated.

Occupational health and ergonomic intervention research in Agriculture farms is a well-known field of study. Most of the information taken from the literature, although it is needed to check the quality of the research on the basis of existing knowledge of methodological assessment tool. Among all the options available, it was important to develop cost-effective programs and framework [20, 23] that can be applied to larger scale quickly.

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Chapter 24
Skin–Bed Interface Pressure on Standard Hospital Mattress for Sitting, Prone, and Supine Posture in Healthy Adults

Sachin S. Shinde and Neela R. Rajhans

Abstract Pressure ulcers (PUs) are common medical problem in bedridden patients. Major contributing factor includes interface pressure (IP) developed over bony prominences due to various extrinsic postural parameters. The cost of PU prevention and treatment is a major burden on the healthcare system. The incidence and prevalence of PUs are considerable even after technological advancement in hospital beds and support surfaces. The work is an attempt toward examining the effects of sitting, supine, and prone postures on skin–bed IP. Total 31 healthy subjects were considered for study and with the help of CONFORMat® pressure mapping system IP at various locations were examined. It is observed that maximum IP is 477 mmHg under knee in prone posture, 634 mmHg at the ischial tuberosities, and 432 mmHg at heel in sitting posture whereas it is observed moderate 213 mmHg at the sacrum and 200 mmHg at shoulder region in supine posture. The author proposes that the study is useful for the caretakers to instruct the patient's effective posture on the bed as well as provides proper inputs for efficient bed mattress design which will further help to reduce and healing of PU.

Keywords Pressure ulcer (PU) · Skin–bed interface pressure · Support surface · Decubitus · Supine posture · Hospital mattress · Necrosis

1 Introduction

PUs (also known as bedsores or decubitus, the word decubitus is taken from Latin word *decumbere*) mean to lie down [1] and defined by [2] as areas of localized damage to the skin and underlying tissue, believed to be caused by pressure, shear, or friction when person is sitting or lying on bed for long period.

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Quadriplegic, neurologically compromised, obese bedridden patient, and certain immobile posture have a high risk of developing PUs [3, 4] those who are limited or impaired mobility. Unrelieved IP due to poor posture, weight, and immobility can lead to decrease in blood circulation in capillary called occlusion of blood vessels. This can lead to oxygen deficiency in tissue and it starts tissue damage called as ischemia and eventually tissue necrosis [5].

Extended hospital stay and bedridden behavior due to surgery, injury to the spinal cord, or an illness restricts mobility even for less than a day, and the pressure of this immobilized body on certain areas of bony prominence restricts the blood flow which further can break down the tissue [6]. An early study conducted by researcher provides that minimizing skin–bed IP reduces the risk of pressure ulcer development. Also it is not clear which turning posture and protocol is best and work effective against pressure ulcer development. Study conducted on 15 healthy adults from hospital for the effects of turning on skin–bed IP concludes that standard turning by experienced nursing staff does not effectively relieve all areas of high IP and further states that support material should be chosen properly to maintain lateral posture to relieve tissue IP. Further study needed to obtain optimum posture to eliminate the area at risk [7].

Excessive pressure above capillary closing pressure between human buttock and seating surface is generally documented as the major cause of the occurrence of PUs [8]. Skin–bed IP mapping involves sensors to quantify the pressure between two contacting objects, like a human body and support surface. Clinicians and researchers use this system most commonly to investigate the surface, risk factors for ulceration, and ulcer prevention protocol [9]. Skin–bed IP measurement is highly sensitive to subject variability and subject placement. No two humans of same anthropometric dimension are anatomically identical, so there is significant variation in IP from person to person. Shelton [10] compared various surfaces of anthropometrically correct mannequins to reduce variations and standard method of subject placement. Mannequins chosen are adequately representing 90% for elderly people in the range of 65–70 years to evaluate the support surfaces. After medical treatment of patient, he is immobilized for some extended period of time. In this duration patient needs frequent mobility to prevent PU developing as a result of loading of skin tissue against the same areas of the body. Such mobility provided by turning the patient requires hospital nurses/word boys which further increase further burdens on caretaker [11]. The various body parts like sacrum, elbow, shoulder blades, and heels are the areas that can break down if the point is kept in one position for long period of time as shown in Fig. 1.

Wheelchai-bound patients need frequent posture adjustment at least every 2 h to relieve skin–bed IP that is being applied to capillaries. This helps to reduce the risk of developing pressure ulcer to some extent. In this paper author proposed

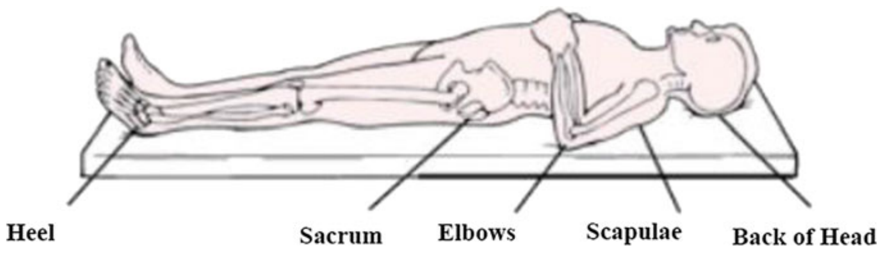

Fig. 1 The prominent pressure points causing PUs in supine position [9]

a design of a system which monitors and give alert through a visual and audible alarm to patient about his/her current positioning and when to adjust their current positioning to restore tissue blood flow effectively. LabVIEW written program and the Tekscan, Inc. CONFORM at pressure mapping system along with the API 2 software package are the major constituents of the system [12]. Thus posture is one of the most significant factors contributing to PU. The work is attempted to assess different postures and to suggest suitable posture to avoid or to recover PU problem.

2 Methodology

2.1 Participants

Participants were students and staffs from college of engineering. A total 23 male and 8 female gave informed consent and participated in the study, with standard hospital mattresses as a support surface. The participants were healthy adults from 20 to 60 years of age (36.7 ± 7.1). Their heights and weights ranged from 1.37 to 1.85 m (1.63 ± 0.04 m) and 39 to 85 kg (63.29 ± 14 kg). Initial data were collected on admission to the trial.

Data were collected from 31 healthy adults from the institute. Mapped with a sensor mat of Tekscan CONFORMat® pressure mapping system and IP profiles were obtained in the sitting, supine, and prone position on standard hospital mattress.

2.2 Experimental Setup

The setup consists of a standard hospital bed mattress, electronic weighing scale, and CONFORMat® pressure mapping system to collect the skin–bed

Fig. 2 Experimental setup

IP. This system consists of a thin, easily foldable body pressure mapping pad, equipped with capacitive sensors. This pad was placed in between hospital bed mattress and the subjects without folds. Sensors in pad develop voltage difference, which increases linearly with the amount of pressure placed on the pad. Pad is connected to the laptop with special Tekscan software (Version 6.0.21.0) which allows taking real-time pressure registration. The pads thinness enables the user to confidently incorporate the sensors into the application without altering the characteristics of the support. The combination of these factors enables precise measurement of the location and magnitude of peak pressures and overall pressure distribution pattern. Figure 2 shows the experimental setup for actual pressure measurements at a different location for all subjects.

2.3 Procedure and Data Collection

For this study participants were positioned in sitting, supine, and prone postures, respectively, with their sacrum, knee, and heal centered on the pressure sensing pad on the hospital mattress. The calibrated interface pressure profile images are captured for supine posture for each participant as shown in Fig. 3a, b. To reduce measurement error in each testing position, before recording the pressure profile there was 15 s period of stabilization for capturing the profile. The procedure was repeated for other 2 postures. Each posture reading took 2–3 min. For each profile image, the mean of 3 readings of the peak pressure in raw which is further converted to mmHg at the sacrum, heel, and knees were used for analysis.

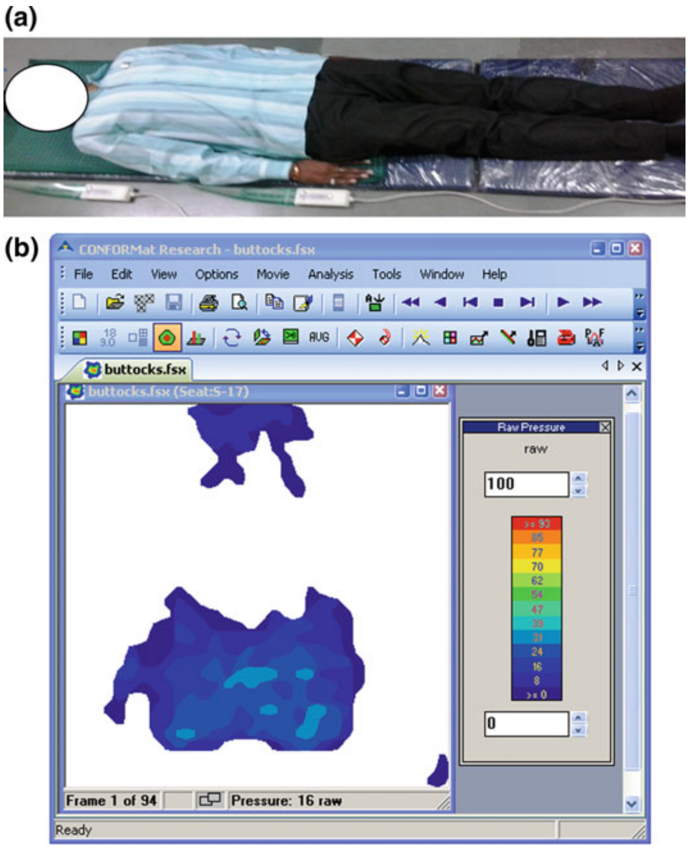

Fig. 3 Data collection. **a** Pressure measurement in supine posture. **b** Pressure images by using Takscan pressure measurement system

3 Results and Discussion

Peak pressures at different locations at different postures are measured and tabulated in Table 1. It is observed that sitting posture develops max IP (Fig. 4) and 61% subjects develop more than mean peak IP. It is also observed that peak pressures at the sacrum and heel change significantly with change in posture.

Postural immobility is the key risk factor for developing PUs, so interventions of different postures with different support surfaces to combat this risk need to focus. Thus this study shows that head, shoulder blades, sacrum and heel are most vulnerable areas in sitting, supine and prone posture that can develop PUs.

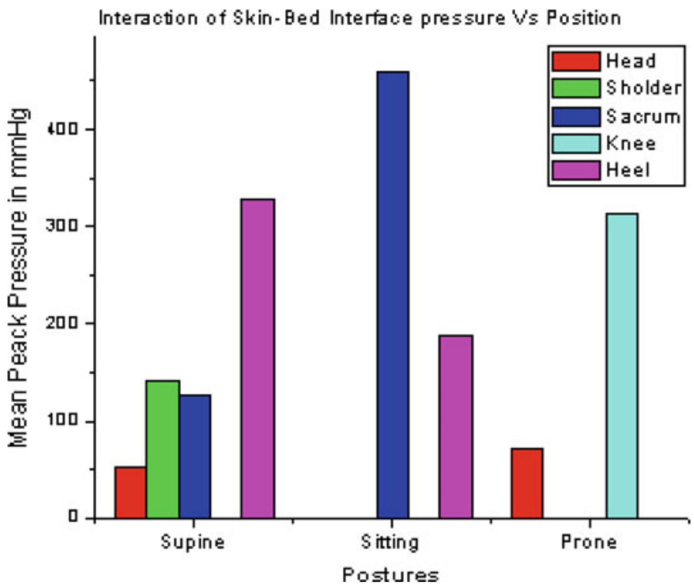

Fig. 4 Interaction of mean peak pressure for different postures

Table 1 Summary of maximum interface pressure outcome

Locations	Peak IP (mm Hg)	*N*	Mean peak IP (mm Hg)	% more than mean IP
Head (Supine)	86	31	53	29
Shoulder (Supine)	200	31	141	45
Sacrum (Supine)	213	31	126	51
Heel (Supine)	467	31	329	48
Sacrum (Sitting)	634	31	460	61
Heel (Sitting)	432	31	189	45
Fore head (Prone)	176	31	71	32
Knee (Prone)	477	31	314	38

4 Conclusion

Despite the continual development of new technologies pertaining to hospital beds and mattress, we are not witnessing a significant reduction in PU patients.

In rehabilitation medicine, instruction of the critically injured patient's posture is one of the important factors for prevention of PU. The present study will contribute and help the healthcare nurses to guide patient's correct posture and repositioning on the bed to reduce and healing of PUs.

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Chapter 25
Design of Continuously Variable Transmission Mechanism for Economy Cars in India

Sanjog Kumar Panda, Abhirup Chatterjee and Debkumar Chakrabarti

Abstract Over the past decades, there has been a great effort towards the development of the Continuously Variable Transmission (CVT) as it offers a continuum of the gear ratios between the two limits. It also helps in meeting the goal of reduced exhaust transmission, enhances the fuel economy and improves the dynamic performance of the vehicle by matching the engine performance to the road conditions and the traffic problems. The purpose of this paper is to improve and popularize the use of CVT in Indian cars in and below 1000 cc vehicle. The basic idea of this is to benefit the Indian citizens especially the elderly and the differently abled people with a comfortable and easy drive on the present day where traffic is the major problem. The basic concept, mathematical calculations, design procedure of the same has been discussed in detail.

Keywords Continuously variable transmission · Continuous gear ratio · Power efficiency · Fuel economy

1 Introduction

The recent Indian scenario of heavy traffic congestion anytime in the city has made it practically impossible for the elderly and the differently abled people to drive even short distances. Therefore an effort should be made to simplify the Indian driving experience by the above-mentioned people, even in the worst traffic situations. This can be accomplished by shifting the driving exercise towards more

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automatic minimizing driver dependence; definitely with no compromise in comfort, speed, power and driver-dependent control of the vehicle. The Continuously Variable Transmission (CVT) system basically comprises two variable diameter pulleys, which are kept at fixed distances and are connected by a belt. Each pulley consists of movable sheaves [1]. The belt (as we are going to use metal belt so we will consider belt hence forth) undergoes both tangential and radial motion depending upon the torque loading conditions and the axial force of the pulley and this result in the variation in the transmission ratios. The pulley attached to the engine output shaft is called the drive pulley and the pulley attached to the shaft of the F&R is called the driven shaft. The torque is transmitted from the drive to the driven pulleys by the friction acting between the belt and pulley surfaces. Presently the vehicles are commonly fitted with a manual transmission mechanism, where the driver has to control three paddles, the steering wheel and the gear-shifting lever while taking care of the traffic rush also—which becomes cumbersome. It would have been greatly beneficial if we could reduce the human-handled components. Transforming from the today's manual gear transmission to the automatic one can better accentuate this, thus promoting the context specific applications of automatic transmission in Indian economy cars. This paper mostly details a one-dimensional metal V-belt CVT and its calculated values for an 800–1000 cc vehicle. The goal is to help Indian citizens from the present day situations of traffic, fuel economy and Indian economy and mostly concerning the elderly and the differently abled.

2 Contextual Relevance of CVT

Unlike traditional automatic transmissions, continuously variable transmissions do not have a gearbox with a set number of gears. The most common type of CVT operates on an ingenious pulley system that allows an infinite variability between highest and lowest gears with no discrete steps or shifts. A CVT is a transmission which can change steplessly through an infinite number of effective gear ratios between maximum and minimum values. This contrasts with other mechanical transmissions that only allow a few different distinct gear ratios to be selected. The flexibility of a CVT allows the driving shaft to maintain a constant angular velocity over a range of the output velocities [2]. This can provide better fuel economy than other transmissions by enabling the engine to run at its most efficient RPM for a range of vehicle speeds.

2.1 Mechanism of CVT

In system of CVT, when the engine is rotating, the rollers in driving pulley create the displacement of the drive pulley and change the CVT ratio by centrifugal force depending on the speed of the crankshaft. The distance between the centers of the pulleys to where the belt makes contact in the groove is known as the pitch radius.

When the pulleys are far apart, the belt rides lower and the pitch radius decreases and vice versa. The ratio of the pitch radius on the driving pulley to the pitch radius on the driven pulley determines the transmission gear ratio. In the driven pulley, weight sets clutch to control the rotating of the rear tire. When engine is idle, the clutch set is not functioned till the rotation is increased. Clutch set is functioned to grab the cover clutch when a certain speed is reached. In cover clutch a special spring is available to control the ratio of diameter.

2.2 The Present Vehicle Features

Weight of the vehicle	m = 965 kg and m + l = 1415 kg
Engine	1197 cc
	Maximum power—84.3 bho @ 6000 rpm Maximum torque—115 Nm @ 4000 rpm
Presently used transmission	Manual Gear box, clutch type, dry single disk
	Gear Ratios—1st–3.545; 2nd–1.904; 3rd–1.280; Thereby, Final Drive ratio—4.388
Vehicle dimensions	
	Length—3850 mm; Width—1695 mm; Height—1530 mm; Wheel Base—2430 mm; Tread Front—1485 mm; Tread Rear—1495 mm; Ground Clearance—170 mm;
Tire size	185/80R14 [8].

3 Calculations

3.1 Determination of the Highest Ratio (e.g., see [2])

The highest ratio is selected so as to achieve the maximum possible speed. It is also used to benefit the highway fuel economy. (Top speed and fuel economy can never be achieved at the same instance).

$$\text{Available Power} \rightarrow \begin{array}{l} \text{pe} = 84.3\ \text{hp}; \\ \text{ef} = 90\%; \\ \text{pt} = \text{pe} \times \text{eff} = 75.87\ \text{hp} = 55{,}802.290\ \text{w} \end{array} \tag{1}$$

$$\text{Thrust Force} \rightarrow \text{Let top speed be 'v' m/s}$$
$$tf = \frac{pt}{v} = \frac{55,802.290}{v}\ \text{N} \tag{2}$$

$$\begin{aligned} \text{Drag force} \rightarrow \quad & \text{df} = \text{cd} \times \tfrac{1}{2} \times r \times v^2 \times \text{ar} \\ & \text{cd} = 0.26; \quad r = 1.2\,\text{kg/m}^3; \quad \text{ar} = 2.593\,\text{m}^2 \end{aligned} \tag{3}$$

The ***maximum velocity*** can be calculated by equating the Thrust force and the Drag force

$$\begin{aligned} & v^3 = \frac{\text{pt}}{\text{cd} \times 1/2 \times r \times \text{ar}} \\ & \text{vm} = 51.6703\,\text{m/s} = 186.013\,\text{km/h} = 115.583\,\text{mph} \end{aligned} \tag{4}$$

$$\begin{aligned} \text{Highest ratio} \rightarrow \quad & \text{rp} = 6000\,\text{rpm}; \quad \text{wd} = 25.65\,\text{inch}; \quad \text{dr} = 4.388{:}1; \\ & \text{hr} = \frac{\frac{\text{rp}\times2\times3.1416}{60}\times\frac{\text{wd}\times0.0254}{2}}{\text{vm}\times\text{dr}} = 0.9027400{:}1 \end{aligned} \tag{5}$$

3.2 Determination of the Lowest Ratio

$$\begin{aligned} & \text{Force due to the slope} \rightarrow m = 965\,\text{kg}; \quad l = 450\,\text{kg}; \quad \text{si} = 57.74; \\ & \text{fos} = 2\ \text{fs} = \frac{(m+l) \times 9.81 \times \frac{\text{si}}{100} \times \text{fos}}{\text{ef}} = 18711.057\ \text{N} \end{aligned} \tag{6}$$

$$\begin{aligned} & \text{Available tangential force in the tyres:} \quad \text{mt} = 115\ \text{Nm}; \quad \text{ce} = 90\% \\ & \text{ft} = \text{mt} \times \text{cf} \times \text{lr} \times \text{dr} \times \frac{\text{wd} \times 0.0254}{2} \\ & \text{lr} = 12.775380{:}1 \end{aligned} \tag{7}$$

3.3 CVT Dimensions

Pulley: Considering that the smaller diameter $d_1 = 50\,\text{mm}$ and that the bigger is d_2 will be so that

$$\text{syh} = \frac{d_1}{d_2}$$

$d2 = 179.43049 \cong 180$ mmwith $\beta = 30°$

Belt [3]: The center-to-center distance for the pulleys being a (>180 mm) = 185 mm

$$\mathrm{bl} = (2 \times a) + \frac{\mathrm{PI}(d_2 + d_1)}{2} \times \frac{(d_2 + d_1) \times (d_2 - d_1)}{4 \times a} = 753.02676 \text{ mm.} \tag{8}$$

3.4 Velocities

(considering the maximum power regime),

$$\begin{gathered}\text{Velocities in the lowest ratio:} \quad n_1 = 6000; \quad n_2 = \frac{n_1}{\mathrm{syh}} = 1521.4804; \\ \mathrm{bs} = \frac{n_1 \times 2 \times pl}{60} \times \frac{d_1}{2} = 15.707963 \text{ m/s}\end{gathered} \tag{9}$$

$$\text{Velocities in the highest ratio:} \quad n_1 = 6000; \quad n_2 = \frac{n_1}{\mathrm{syh}} = 21{,}531.659;$$

$$\mathrm{bs} = 56.369753\,\mathrm{m/s}$$

3.5 Forces

Friction coefficient: μ = 0.3

Therefore, the effective friction coefficient will be calculated by

$$\mu.e = 1.15911$$

Belt tensions in the lowest ratio:

$$\begin{gathered}\mathrm{syh} = 0.9435274; \quad d_1 = 50 \text{ mm}; \quad d_2 = 180 \text{ mm} \\ \alpha = 2 \times a \times \cos\left(\frac{d_2 - d_1}{2a}\right) = 39.04834\end{gathered} \tag{10}$$

$$t_{12} = e^{\mu e \alpha} = 6.6595659; \quad t_1 = 199.8665 \text{ N}; \quad t_2 = 52.06196\,\mathrm{N};$$

$$\mathrm{sl}^2 = \mathrm{t}_1^2 + \mathrm{t}_2^2 - 2\mathrm{t}_1\mathrm{t}_2\cos\alpha; \quad \mathrm{sl} = 394.7273\,\mathrm{N}; \quad \mathrm{acf} = \frac{\left(\frac{\mathrm{pe}}{\mathrm{bs}}\right)}{\mu e} = 405.3724\,\mathrm{N}$$

Belt tensions in the highest ratio:

$$\begin{aligned}&\mathrm{hyl} = 0.2659864; \quad && d_1 = 179.43049\,\mathrm{mm}; \\ &d_2 = 50\,\mathrm{mm}; && \alpha = 39.04834\end{aligned}$$

4 Discussion

In India, currently CVT is mostly installed in 1500 cc onward cars only, those pricing a minimum of 9.8 Lakhs (ex-showroom). However, a greater number of 800–1000 cc cars ply on road compared to 1500 cc and above models. Considering the Indian economy even today, 9.8 lakhs does not seem to be an affordable deal for everyone. So a 1000 cc vehicle installed with CVT can support not only the elderly and the differently abled but it can fascinate the common Indians also [4]. This can also help the present environmental conditions, where pollution is a key concern. Currently the effectiveness of the above is being tested with prototypes for aspects like engineering efficiency and universal usability, i.e., uncomplicated and stress-free driving even for the elderly and the differently abled [5, 6].

5 Conclusion

Use of a CVT mechanism facilitates the driver to handle the accelerator, brake pedals and the steering wheel only, thus enabling one to concentrate more toward the traffic. It supports in reducing exhaust transmission, thereby enhancing the fuel efficiency and finally improving the dynamic performance of the vehicle.

Appendices

1. Description of Equations

Equation 1—calculation to find available power after transmission
Equation 2—calculation to find the thrust force
Equation 3—calculation to find the drag force
Equation 4—calculation to find maximum speed of the car
Equation 5—calculation to find the highest ratio
Equation 6—calculation to find out factor of safety
Equation 7—calculation for the tangential force acting on the tires
Equation 8—calculation of belt length
Equation 9—calculation of belt speed
Equation 10—calculation to find the smallest wrap angle

2. Indices and Abbreviations

μ Coefficient of friction
a pulley center to center distance (mm)

ar vehicles projected frontal area (m^2)
bl belt length (mm)
cd coefficient of drag force {depends on the aerodynamic design of the vehicle
ce clutch efficiency
cf correction factor [0.91–0.99]
cpf clamping force (N)
d_1 smaller diameter (mm)
d_2 larger diameter (mm)
df drag force
dr differential ratio
ef transmission efficiency (including rolling resistance)
fos factor of safety
fs force due to slope
ft tangential force on the tires
hr high ratio
l maximum load (kg)
lr low ratio
m mass (kg)
mt maximum engine torque (Nm)
n_1 rotational speed of driver pulley (rpm)
n_2 rotational speed of the driven pulley (rpm)
pe Engine power (hp)
pi percentage inclination
pt available power after transmission (hp)
r air density (1.2 kg/m^3)
rp rpm at maximum power
si slope inclination
sl shaft load (N)
syh symmetric high ratio
syl symmetric low ratio
t_1 belt load tension 1
t_{12} ratio of the belt forces
t_2 belt load tension 2
tf thrust force (N)
v speed of the car (m/s)
vm maximum speed of the vehicle (m/s)
wd wheel diameter (inch);
α smallest wrap angle (in °)
β pulley groove angle (in °)

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Chapter 26
A Brief Procedure for Ergonomic Design of Hand Tool for Small-Scale Industries

M.K. Sain, M.L. Meena, G.S. Dangayach and A.K. Bhardwaj

Abstract Ergonomics is considered as a science concerned with the interactions among humans, machinery and other elements of a system. The hand tools used in labour-intensive small-scale industries like agriculture, food processing, furniture, handicraft, brick kilns, etc. are traditional and designed un-ergonomically, which causes musculoskeletal disorders (MSDs) and other health problems among workers. Various studies on ergonomic design of hand tool have suggested that ergonomic improvements have a great impact on occupational disorders, human working and safety in manual operation. Ergonomically designed hand tools reduce the MSDs upto a significant level. The paper presents various steps of a brief framework for hand tool design based on the literature survey.

Keywords Design · Ergonomics · Hand tool · Musculoskeletal disorders · Small-scale industries

1 Introduction

Hand tools have been in use for thousands of years, initially for hunting and gathering food. These are the primary means to extend the capabilities of the human hand [1].

In a country like India, the hand tools are used in various small-scale industries (SSIs) including unorganized sector. The SSIs are the backbone for the growth of

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the country and this contributes about 40% of the gross industrial value added in the economy of India (MSME 2014). Also, the contribution of SSIs in the country's gross domestic product (GDP) is about 8.72% [2]. The SSIs are labour-intensive in which the use of traditionally designed hand tools and un-ergonomic workplaces result in musculoskeletal disorders (MSDs) among workers [3].

The use of ergonomic principle to design workstation and hand tool is the best solution for work-related MSDs and other occupational health problems [4, 5]. The workers of the Indian SSIs would be highly benefited if ergonomic principles are used to modify workstations and hand tools [4].

This research paper includes peer-reviewed journal articles, conference papers aiming to describe MSDs, occupational health and ergonomic design of hand tools. Government websites are also referred for describing the current scenario of SSIs.

2 Procedure of Ergonomic Design of Hand Tool

On the basis of literature review, the process of ergonomic design of hand tool can be divided into two phases: (i) field study and (ii) hand tool design which is elaborated in Fig. 1.

2.1 Field Study

The field study consists of two stages: posture analysis and questionnaire survey. Posture analysis can be done by already available techniques as per requirement, or these techniques can be used in combination for better results. The commonly used posture analysis techniques are as follows:

- KIM (Key Item Method) by Steinberg et al. [6]
- LUBA (Loading on the Upper Body Assessment) by Kee and Karwowski [7]
- OCRA (Occupational Repetitive Actions) by Occhipinti [8]
- OWAS (Ovako Working Posture Analysis System) by Karhu et al. [9]
- REBA (Rapid Entire Body Assessment by Hignett and McAtamney [10]
- RULA (Rapid Upper Limb Assessment) by McAtamney and Corlett [11]
- SI (Strain Index) by Moore and Garg [12]
- ULRA (Upper Limb Risk Assessment) by Roman-Liu [13].

Keeping in mind the results of posture analysis, a questionnaire survey using modified Nordic Questionnaires is conducted which gives required inputs for hand tool design. The study consists of three parts including (a) personal details, (b) Nordic questionnaire for musculoskeletal disorders and (c) anthropometric dimensions [14]. Based on the anthropometric data and occupational health problems the hand tool is designed.

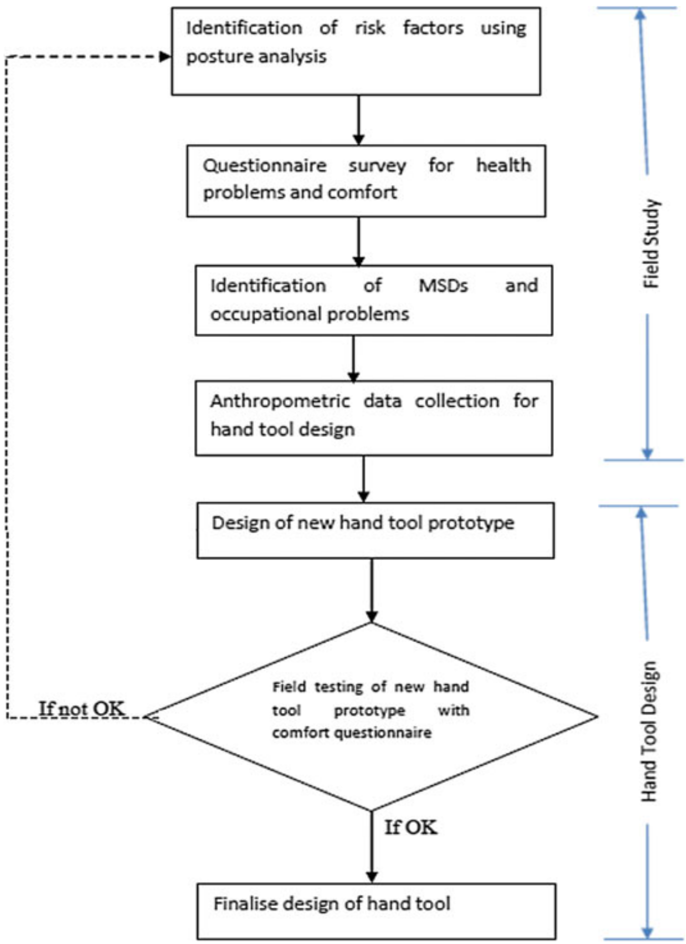

Fig. 1 Procedure diagram of hand tool design

2.2 *Hand Tool Design*

To reduce the MSDs hand tools are designed using ergonomic principles and anthropometric data. To ergonomically design a hand tool or work station, it is necessary to systematically and thoroughly investigate the factors affecting the design of a product [15, 16]. In this respect, from the established ergonomic design principles, recommendation, checklist and guidelines, a conceptual model for understanding various factors influencing the ergonomic design of hand tool system is proposed as shown in Fig. 2.

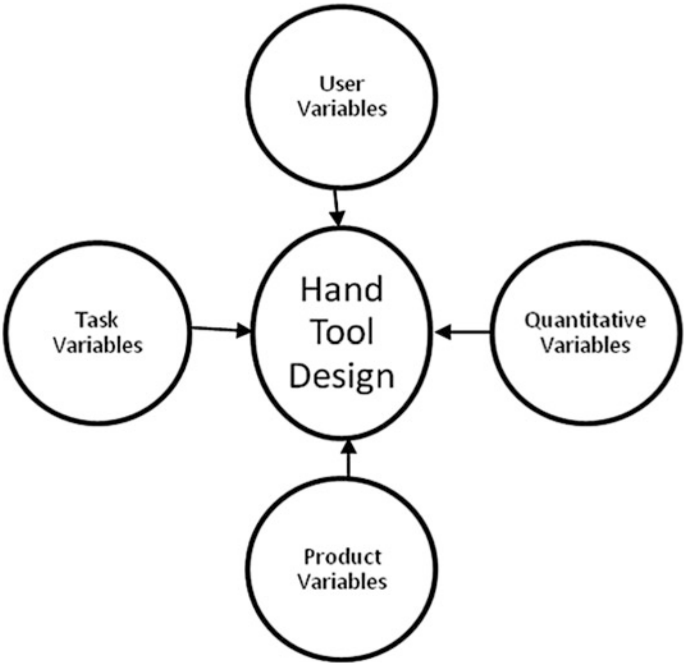

Fig. 2 Factors affecting hand tool design

These necessary variables are as follows [15, 17, 18].

- User variables like muscular strength, body dimensions, gender and age.
- Task variables like posture required, working space and task requirement.
- Product variables like dimensions, shape, texture and grip.
- Qualitative variables like functional user needs, traditional needs and affective user needs.

Discomfort in using hand tools can be reduced by optimization of the functionality and physical interaction. However, appearance of hand tools can play a major role in selection between hand tools with common functionality and physical interaction [18]. To prioritize the factors, analytical hierarchy process (AHP) and other similar tools can be used.

Considering the mentioned four variables, hand tools are designed ergonomically. For the designing purpose, available compatible ergonomic CAD software can be used [19].

Thus, the hand tool design phase can be summarized as follows [5, 18, 20].

- Studying hand tools currently used in industry for considering design or redesign requirements and their specifications like weight, handle texture and shape [21].
- Developing new models of hand tools according to hand anthropometric data of workers and ergonomic design principles [22, 23].

- Making prototypes.
- Testing the prototypes based on a comfort questionnaire.
- Redesigning the prototypes according to the results of comfort survey [24].

After designing, again posture analysis is done to see the significance of the change in risk factors and on the basis of change in risk factors the design can be finalized. The hand tool design can be refined continuously by further improvements based on user's survey.

3 Conclusions

Studies show that a mismatch between workers and the hand tools can cause musculoskeletal disorders and other health problems which reduce the productivity. This mismatch can be minimized by ergonomic design principles, however; it is a complex part of the hand tool design. The literature shows that work has been done on the design of some specific hand tools, some checklists are also developed to an ergonomic analysis of hand tools and guides for the selection of hand tools are also there. There is a need of general design procedure for hand tools using ergonomic principles. The procedure given in this paper provides a general ergonomic design of non-powered hand tools. This brief procedure will be a benefit to design hand tools based on ergonomic design principles in a systematic way.

Further work is needed in the development of the detailed procedure to design, including design for material and design for manufacturing for both non-powered and powered hand tools.

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Chapter 27
Designing Washroom for Wheelchair Users in Vocational Training Schools

P. Shivalkar and M.K. Chauhan

Abstract This research attempts to study the washroom areas designed for wheelchair users in three vocational training schools in Mumbai and recommend the changes needed to improve the comfort. 50 wheelchair users (19 females and 31 males) from the age group 10–40 years were selected. The major problems faced by the users were height of commode, washbasin and door handle; unavailability/inappropriate heights of grab bar, inadequate circulation space for wheelchair to maneuver, low lighting levels, no fire safety measure, unsafe door and flooring. Based on the responses of the wheelchair users, anthropometric dimension and measurement of various features in washroom, the designs were proposed.

Keywords Wheelchair users · Vocation · Design · Disability · Washroom

1 Introduction

About 10% of the global population, i.e., about 650 million people, have disabilities [10]. Studies indicate that, of these, around 10% require a wheelchair. Out of the estimated 650 million people with disabilities in the world, 400 million live in the Asian and Pacific region and over 40% of them live in poverty [11]. The data of Census 2011 [6] on disability says that in India disabled population has increased by 22.4% between 2001 and 2011.

People with disabilities face different types of barriers such as physical, social, communication, education and environmental barriers [5]. On the basis of the impact on persons with disabilities, Whiteneck and colleagues [9] have categorized environmental barriers as Accessibility, Accommodation, Resource availability, Social support, and Equality. Among the various barriers, toilets and washrooms

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create accessibility challenges, for those in wheelchairs. Accessible washrooms need a larger space than other cubicles to allow space for a wheelchair to maneuver. This space is also useful for people who are not necessarily wheelchair users, but still need physical support from someone else. Designers need to address these issues by providing more space and bars for users to grab and hold during transfers.

Design details vary from country to country, but there is a fair degree of unanimity on the structural elements that are required: "Whether it is called accessible, barrier-free, adaptable or multi-generational, the common thread is housing that can easily be adapted to suit the physical needs of most people, including those who are disabled, without major structural alteration, and that can, without adaptation, be visited by wheelchair users. Its common design elements are—level access—adequate door widths—reasonable circulation space in halls and passageways and—an entrance level toilet" [1, 4].

The problems of wheelchair users are many, the most common problem being performing washroom routine. Based on literature, the most difficult part for the disabled was to move to the washroom bowl and in most of the cases without escort it is not possible to carry out this activity, thus making them vulnerable and dependent. Therefore, the current study is focused on studying the problem related to the design of the washrooms used by wheelchair users from three vocational training institutes and suggests the improvements for comfortable mobility, accessibility, safety, and optimum circulation space while using washrooms.

2 Methodology

This is a cross-sectional study conducted on 50 wheelchair users who were taking training in three different vocational schools in Mumbai: School A for Age group 10–20 years; School B for Age group 20–30 years and School C for Age group 30–40 years.

The convenient sampling method was used to collect the data and information. 50 wheelchair users from three different training schools comprising of 31 males and 19 females were part of the study. Only wheelchair users undergoing vocational training in institutions were included in the study. Prior permission to conduct the study was taken from the head of each training school and observations and measurements checklist were made based on the existing washrooms design. The first aspect of the study was observation that included the observations related to flooring, circulation spaces, ventilation, and lighting. The second aspect incorporated the measurements of washroom and washroom accessories with Colt 5 m tape. The dimensions recorded were height of washbasin, commode, grab bars, mirror, switch board, door handles, and wheelchair. The lighting levels in the washroom were measured with the help of Digital Lux Meter (MEXTECH LX-1010B). The third aspect of the study was interview schedule consisting of questions related to Accessibility, Safety with respect to material used, types and design of handles, signage visibility, fire protection, ease of comfort, etc.

Analysis of the data was done using descriptive statistics and the results are presented in percentage enumeration. AutoCAD software was used to make the existing and proposed plan of the washroom areas.

3 Results and Discussion

3.1 General Characteristics of the Subjects

The current study was carried out on 50 wheelchair users belonging to three vocational schools in Mumbai from the age group 10–40 years with 31 (62%) males and 19 (38%) females. The general characteristics of the subjects are presented in Table 1.

Table 1 showed that the maximum number of respondents (n = 30) belonged to age group 31–40 years. With respect to types of disability it is seen that 56% of subjects had both legs affected, 38% had one leg affected and 20% with one arm affected. Further it was observed that 48% of subjects had disability by birth while 28% had due to some diseases in childhood and 22% had due to accident.

Table 1 General characteristics of the subjects

Aspects	School A (n = 10) 10–20 years	School B (n = 10) 20–30 years	School C (n = 30) 30–40 years	Total (n = 50) 10–40 years
No. of subjects	10 (20%)	10 (20%)	30 (60%)	50 (100%)
Gender				
Males	6 (60%)	5 (50%)	20 (67%)	31 (62%)
Females	4 (40%)	5 (50%)	10 (33%)	19 (38%)
Type of physical disability				
Both leg affected	5 (50%)	7 (70%)	16 (53%)	28 (56%)
Both arm affected	1 (10%)	0	0	1 (2%)
Both leg and both arm affected	2 (20%)	0	2 (7%)	4 (8%)
One leg affected	3 (30%)	4 (40%)	12 (40%)	19 (38%)
One arm affected	4 (40%)	1 (10%)	5 (17%)	10 (20%)
Stiff back and hips	2 (20%)	1 (10%)	2 (7%)	5 (10%)
Reason for disability				
By birth	8 (80%)	5 (50%)	11 (37%)	24 (48%)
Diseases	1 (10%)	4 (40%)	9 (30%)	14 (28%)
Accident	1 (10%)	1 (10%)	9 (30%)	11 (22%)

3.2 Existing Design Features of Washroom Area

Table 2 describes the existing design features of the washrooms area.

The results of the existing design features of schools (Table 2) showed that the existing size of the toilet in School A had comfortable moveable space while in School B and School C had less circulation space. School B had two small and narrow adjacent toilets cubicles with door width 800–900 mm and had manual locking system. Schools B and C had half walls tiled and other half was painted. For flooring ceramic tiles were used in Schools A and C and kota in School B. For lighting incandescent bulb and tubelight was used in School A and B while in School C no artificial light was provided. The recommended lighting levels in washrooms should be 300 lx [4], but here in all three schools the lighting levels were much below the recommended levels. In School B at commode the lighting recorded was 237 which was little better than other areas in washroom. School A had better lighting than Schools B and C. The height of the switchboard was high in school A and B while in School C it was comfortable. The height of washbasin, tap, mirror, WC and grab bar was more in all schools; while in School A the grab bar was not provided. The fire safety equipment was not provided in any school.

3.3 Subjective Responses of Wheel Chair User for Washroom Area

The subjective responses about the facilities and features present in the existing washroom areas were recorded. The wheelchairs used by subjects did not pose any

Table 2 Existing design features of washroom area

Washroom details	School A	School B	School C
Washroom area[a]	2315 × 1460	1150 × 2000/1160 × 2000	2640 × 1400
Door width[a]	900	800	900
Size of door handle	Small	Small	Small
Wall finishes	Wall tile	Paint and wall tile	Paint and wall tile
Flooring material	Ceramic tile	Kota	Ceramic tile
Lighting	Tube light	Incandescent bulb	Not available
Electric switch point height[a]	1280	1500	1200
Basin size[a]	500 × 400 × 890	370 × 550 × 800	520 × 400 × 800
Mirror[a]	1200 × 300	1200 × 750	960 × 1300
Water closet[a]	500 × 400 × 450	600 × 450 × 550	590 × 400 × 450
Grab bar size[a]	Not available	720 × 1300	2590 × 700
Fire safety system	Not available	Not available	Not available

[a]All measurements are in mm

Table 3 Subject responses of the subjects on existing facilities and features of the washroom

Design aspects	School A (n = 10)	School B (n = 10)	School C (n = 30)	Total (n = 50)
Poor visibility of signage	8 (80)	9 (90)	25 (83)	42 (84)
Door opening act not comfortable	2 (20)	2 (20)	0 (0)	4 (8)
Extra force needed to open door	5 (50)	4 (40)	18 (60)	27 (54)
Inadequate circulation spaces	7 (70)	6 (60)	10 (33)	23 (46)
Height of grab bar not comfortable	–	5 (50)	9 (30)	14 (28)
Height of washbasin not comfortable	4 (40)	6 (60)	8 (27)	18 (36)
Commode seat height Not comfortable	3 (30)	7 (70)	23 (77)	33 (66)
Unsafe flooring	4 (40)	2 (20)	5 (17)	11 (22)
Unsafe door	2 (20)	3 (30)	7 (23)	12 (24)
Washbasin edges unsafe	–	4 (40)	–	4 (8)
Inadequate lighting levels	1 (10)	6 (60)	14 (47)	21 (42)

All figures in brackets denote percentages (%)

problems as they were adjustable and were manufactured by these schools themselves. Results showed that 84% subjects reported the signage having poor visibility, 54% felt that doors needed extra force to open and 46% of subjects found circulation spaces inside the washroom inadequate (Table 3).

In School A there were no grab bars in washroom while in other two schools grab bar were available, but 28% subjects found height uncomfortable. 36% of subjects felt washbasin height as uncomfortable while 66% of subjects reported commode height not comfortable. In terms of safety aspects, 22% said flooring was unsafe while 24% reported door unsafe and 8% reported unsafe washbasin edges. 42% users found lighting levels inadequate and in school C there was no artificial light provided.

4 Proposed Design Features

Table 4 describes the proposed design features of the washroom area for wheelchair users where the needs, safety aspects, circulation spaces, heights, lighting, safety, and signage were considered.

Sharma V (Access Consultant, Accessibility, India [7]) in his study on manual wheelchair users found that the actual measurements and Indian standards [3, 8] vary with the present range of wheeled mobility users and recommended that changes in codes and standards are needed to reflect the needs of the local Indian population.

The proposed design features presented in Table 4 were made on the information provided by the subjects and dimensions of existing washrooms. According to CPWD, Ministry of urban Affairs and Employment, India [2] the minimum size of

Table 4 Proposed design features of washroom area

Washroom details	School A (n = 10) 10–20 years	School B (n = 10) 21–30 years	School C (n = 30) 31–40 years
Washroom area[a]	2315 × 1460	2300 × 1850	2640 × 1700
Door size[a]	1000	1000	1000
Types of door Handles	D pull handle	D pull handle	D pull handle
Wall finishes	Wall tile	Wall tile	Wall tile
Flooring material	Non-skid tile	Non-skid tile	Non-skid tile
Lighting	Led/CFL bulb	CFL bulb	CFL bulb
Electric switch point (mm)	900	1000	1200
Basin size[a]	510 × 400 × 650	630 × 400 × 700	415 × 650 × 700
Tap	Sensor	Sensor	Sensor
Mirror[a]	1300 × 800	900 × 1500	900 × 1600
Water closet[a]	525 × 337 × 300	590 × 415 × 400	570 × 330 × 450
Grab bar size[a]	900 × 1200 × 600	900 × 1200 × 700	2590 × 600 × 700
Fire safety system	Sprinkler, smoke detectors	Sprinkler, smoke detectors	Sprinkler, smoke detectors

[a]All measurements are in mm

the toilet should be 1500 mm × 1750 mm. Thus in School B two adjacent, narrow toilets were converted into one comfortable toilet. The door sizes in all schools were suggested to increase to 1000 mm. D type door handles were suggested at lower heights. In all schools wall tiles and non-skid flooring were recommended. CFL bulbs with proper height of switchboard were suggested. As per the anthropometric dimensions the height of the washbasin, mirror, WC and grab bar was suggested (Table 4). Sensor/pressure types of taps are proposed for easy reachability.

5 Conclusion

Based on the anthropometric data collected and subjective responses from field survey; it was found that using the washroom was a challenging task for the wheelchair users, thus indicating the need to redesign. The present study found that the wheelchair users in the vocational training schools faced many problems while using the washroom. There was circulation constraint; height of commodes, washbasin and door handles was more; accessories and grab bars were uncomfortable to use, flooring was slippery and lighting levels were found to be very low. There was no provision for fire and emergency alarm for hazard. Overall there is a need to understand the needs of disable population and design the washrooms and wheelchairs as per their need which will make them independent.

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Chapter 28
Intra- and Inter-reliability of Cervical Goniometer Used to Measure Cervical Range of Motion in Young Adults

Shivani Chowdhury Salian and Arushi Tiwari

Abstract *Objective*: To determine the intra- and inter-reliability and validity of indigenously designed cervical goniometer in comparison with CROM instrument in young adults. *Methodology*: 198 subjects participated in this study. All the subjects were then interviewed through a questionnaire and needful assessment was done using cervical goniometer and CROM instrument. All the measurements were made thrice using both the instruments by both the investigators. *Results*: The interclass and intraclass reliability of cervical goniometer designed indigenously in the School of Physiotherapy is excellent as shown by the ICC and Cronbach's values. Reliability score of cervical goniometer ranged from 0.999 to 0.931 for all cervical movements in comparison with CROM instrument which suggests a greater consistency in measurements and tool can be considered reliable for the measurements. Difference of average of all the cervical range of motions are insignificant as the values of one-way analysis of variance, p value is >0.05—both the equipments were compared using Pearson's correlation test with coefficient values ranging from, $p = 0.125$ to shows difference between two measurements is insignificant (since $P > 0.05$). Correlation between the values obtained using indigenously designed cervical goniometer and CROM instrument for all movements was considered excellent at $p < 0.05$. One sample T test was done to measure the validity for the two techniques and Bland Altman graph to check the pattern of scatteredness. Regression analysis was done to find out the bias in the measurements. Values of regression, $F = 2.368$ and $p > 0.05$, show that the measures are neither underestimated nor overestimated. *Conclusion*: Good correlation between

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neck ROM measurements obtained from cervical goniometer and CROM instrument ascertains that the technique and the assessment equipment designed indigenously is valid and reliable.

Keywords Cervical goniometer · CROM · Young adults · Reliability and validity

1 Introduction

Neck anatomy is well-engineered structures of bones, nerves, muscles, ligaments, and tendons. It is a delicate-housing the spinal cord that sends messages from the brain to control all aspects of messages from the brain to control all aspects of the body while also remarkably flexible, allowing movement in all directions. There are 6 movements in the cervical spine, Flexion (Flex), Extension (Ext), Flexion and extension movements are controlled by C5–C6 and C6–C7 segments of spine. Left Rotation (Lt.Rot), Right Rotation (Rt.Rot). Rotations are controlled by the first two segments of the cervical spine, specifically the atlas (C1) and axis (C2). Lastly; left-side flexion (Lt.SF) and right-side flexion (Rt.SF).

1.1 Instruments Used for Measuring Cervical Range of Movements

CROM instrument is manufactured by the Foreign Company (Fig. 1). A magnet bar is required to be worn around the neck to measure rotations in the horizontal plane. This makes it difficult at times for people who cannot use magnets around their chest, like people with electromagnetic devices fixed in the body as a pacemaker or

Fig. 1 CROM

artificial valves, etc. Moreover, since it is not indigenously manufactured and sold in India, the cost of the equipment is very high and not feasible for use by masses in health care.

1.2 Purpose of This Study

To assess the reliability and validity of an indigenously devised cervical goniometer that can be used clinically to measure movements of the cervical spine (Figs. 2, 3 and 4).

1.3 Ergonomic Relevance of the Present Study

The present study signifies the invention and use of a cervical goniometer designed indigenously by the author, which can be cost-effective and easy to use in an ergonomic evaluation set up (Fig. 2).

Ergonomics involves the examination of various factors like range of motion (ROM), flexibility and strength to extrapolate the findings in the assessment of work related musculoskeletal disorders. Cervical Goniometer can be used to evaluate ROM of cervical spine in assessing the job and task analysis in workers. For example, to assess the kinetics and kinematics of the cervical spine in professionals working in the computer and software industry, IT sector, banks, etc.

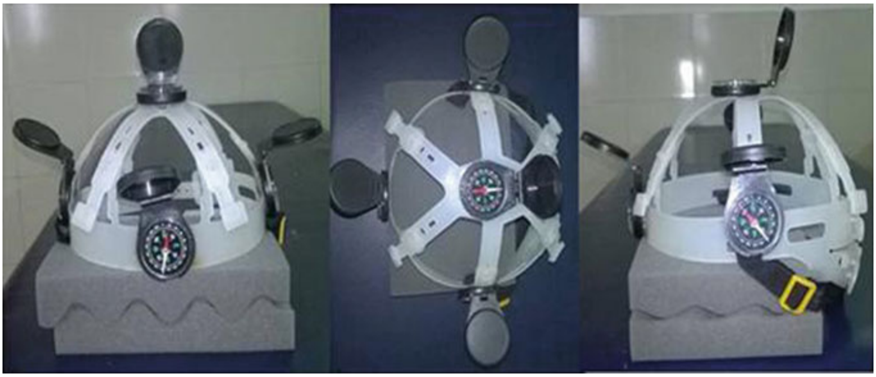

Fig. 2 Indigenously designed cervical goniometer

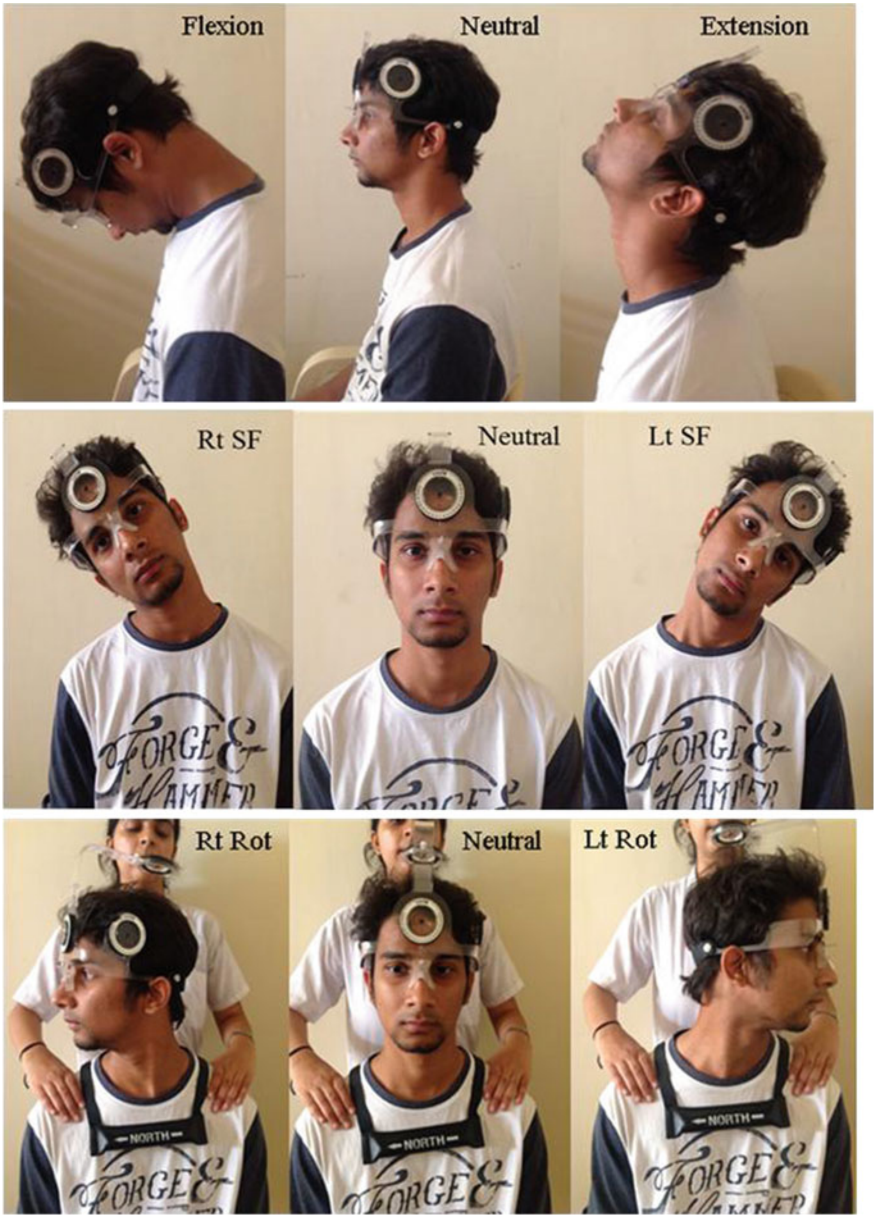

Fig. 3 Measuring cervical ROM with CROM

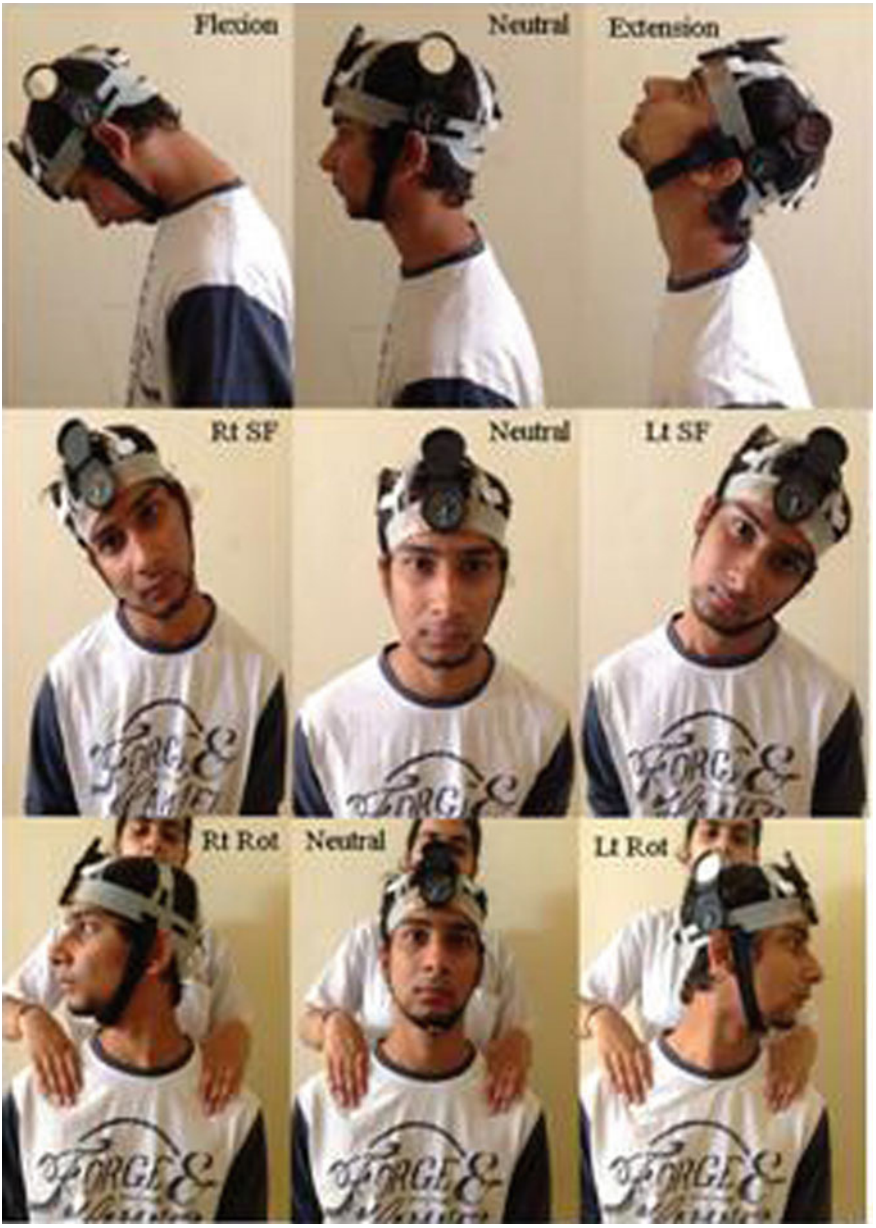

Fig. 4 Measuring cervical ROM with indigenously designed cervical goniometer

2 Methodology

Two hundred asymptomatic subjects aged between 18 and 25 years of both genders participated in this cross-sectional study designed. The protocol was sanctioned by the Ethics Committee of D.Y. Patil University, Nerul, Navi Mumbai. A cross-sectional study within 6 months was carried out in the musculoskeltal laboratory of School of Physiotherapy, D.Y. Patil University, Nerul Navi Mumbai. Subjects above the age of 25 years were excluded from the study.

2.1 Procedures of Measuring Cervical Movements Using the Two Goniometers

All cervical ranges of movements of the participating students were evaluated using cervical goniometer and CROM. For all the cervical movements, three consecutive values were obtained using both the goniometers by two investigators to ascertain the intra- and inter-reliability of the equipment. Average of these three readings were taken to determine inter- and intra-correlation of the instruments.

2.2 Statistical Analysis

Analysis was done using SPSS version 16.

2.2.1 Tests Used

The data presented according to the *T* test where $p > 0.05$. The intra and inter class correlation coefficient was used to verify inter and intra-investigator reliability of the mean cervical ROM values for the new cervical Goniometer. Pearson's correlation coefficient was used ($p > 0.05$) which shows very good correlation in the study. One sample *T*-test was done to measure the validity for the two techniques and Bland Altman graph to check the pattern of scattering. Regression analysis was done to find out the bias in the measurements.

2.2.2 Reliability

Cronbach's alpha value was used to analyze the reliability of both the equipments for all the movements in the present study—the interclass and intraclass reliability of cervical goniometer designed indigenously in the School of Physiotherapy was ascertained by using ICC and Cronbach's values.

2.2.3 Validity Testing

One-way analysis of variance (ANOVA), P value is >0.05. Both the equipments were compared using Pearson's correlation test.

2.2.4 Measurement of BIAS

Regression plots were used to assess the BIAs in the readings taken.

3 Results

3.1 Reliability

The interclass and intraclass reliability of cervical goniometer designed indigenously in the School of Physiotherapy is excellent as shown by the ICC and Cronbach's values as shown in Table 1.

The intra- and inter-examiner reliability of the mean cervical ROM values obtained via new cervical goniometer was considered excellent for all cervical movements.

3.2 Validity

Difference of average of all the cervical range of motions is insignificant.

Both the equipments were compared using Pearson's correlation test with coefficient values ranging from $p = 0.125$ to 0.365 (Table 2) shows the difference between two measurements is insignificant (since $P > 0.05$). Therefore the indigenously designed goniometer gives comparable readings as the CROM.

Table 1 Intra class correlation (ICC) values for intra- and inter-examiner reliability of the values for cervical range of motion obtained by means of cervical goniometer

Movements	Cronbach's alpha value	
	Interclass coefficient	Intraclass coefficient
Flexion	0.914	0.951
Extension	0.956	0.976
Right lateral flexion	0.892	0.943
Left lateral flexion	0.872	0.931
Right axial rotation	0.998	0.999
Left axial rotation	0.983	0.991

Table 2 Comparison between mean values for cervical range of motion obtained by means of CROM instrument and cervical goniometer

Movement	*N*	Mean difference	Std. deviation	Significance (2-tailed) *P* value
Flexion	198	0.2615	4.915	0.455
Extension	198	0.253	5.544	0.522
Right lateral flexion	198	−0.1066	4.9234	0.761
Left lateral flexion	198	0.0806	4.72902	0.808
Right axial rotation	198	0.0731	5	0.828
Left axial rotation	198	−0.3296	5032	0.4

Table 3 Pearson's correlation between the values obtained via cervical goniometer and CROM instrument

Pearson's coefficients values					
Model	Un-standardized coefficients		Standardized coefficients	*t*	Sig.
	B	Std. error	Beta		
Avg FLEX	0.14	0.091	0.109	1.539	0.125
Avg EXTEN	−0.489	0.074	−0.426	−6.592	0
Avg RFLEX	−0.591	0.068	−0.525	−8.645	0
Avg LFLEX	−0.284	0.088	−0.224	−3.215	0.002
Avg RROT	0.052	0.048	0.077	1.088	0.278
Avg LROT	0.055	0.06	0.065	0.911	0.364

3.3 Correlation Between the Values Obtained via Indigenously Designed Cervical Goniometer and CROM Instrument

Pearson's correlation for all movements was considered excellent at $p < 0.05$. Table 3 shows the findings of the analysis.

3.4 Measurement of BIAS

Values of regression, $F = 2.368$ and $p > 0.05$ which shows that the measures are neither underestimated nor overestimated. Table 4 shows the result of the analysis. Thus the values show that there is no BIAS in the readings of the goniometers.

Regression graphs showed that the values do not scatter to a great extent and are clustered towards the central line of the graph, thus depicting more reliability and less scatter.

Table 4 Regression table of measurement of BIAS

Regression model	Sum of squares	d*f*	Mean square	*F*	Sig.
Flexion	56.815	1	56.815	2.368	0.125
Extension	1099.08	1	1099.08	43.457	0.000
Right lateral flexion	1318.298	1	1318.298	74.744	0.000
Left lateral flexion	214.094	1	214.094	10.338	0.002
Right axial rotation	26.453	1	26.453	1.184	0.278
Left axial rotation	25.142	1	25.142	0.829	0.364

4 Conclusions

The present study suggests that there exists a greater consistency in measurement of cervical ranges and the indigenously designed cervical goniometer is considered reliable for the same. The good correlation between new cervical goniometer and CROM instrument shows these techniques present interchangeable difference.

The insignificant difference in the cervical ranges of motion measured by both, the CROM and cervical goniometer validates the cervical goniometer with the CROM.

Since new cervical goniometer gives high reliable evidence it can be used by Indian population of physiotherapist to measure cervical ranges of motion.

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Part VI
User Experience

Chapter 29
Number Plate Design for Bicycles: An Approach from Aesthetic and Ergonomic Perspective

Mohammad Shahid, Subir Dey, Subhajit Chandra, Anmol Srivastava, Ashish Kumar Yadav, Shilpi Bora, Pallavi Rani and Debkumar Chakrabarti

Abstract Need for design of a part or as a whole of a utility item/issue and ergonomics considerations interact in an intertwined way while re-looking the issue either for betterment of existing product or to develop a new one. Around 4000 students of 13 hostels use bicycles in IIT Guwahati campus and identity of bicycles is an issue. The present study looks into the possibilities of using identity labels on bicycles being used in IIT Guwahati campus by the students of different hostel resident. Attempt has been made to develop an ergonomically visible and aesthetically appealing numbering system with specific attention to information flow presentation for easy readability and legibility in both static and moving conditions. Study was conducted through placing relevant information using horizontal and vertical orientation on the mudguard. This study was done with the observational and experimental analysis of the design. Results show that instead of horizontal orientation, the vertical placement on mudguard area is preferred. It was clearly found that the new design was better in terms of readability, legibility, and design aesthetics.

Keywords Bicycle number plate · IIT campus students' requirement · Design experiment · Information flow presentation

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1 Introduction

Design is ubiquitous and essential in everyday life. Whether a person is using a well-designed pen for writing or wearing a suit in a space-craft, design and ergonomics interact in an intertwined way. It could be noticed in minutest details of nature to the largest extent of civilization so far.

The present study of a number plate design for bicycles in the IIT Guwahati campus was considered in order to provide a uniform numbering system and solution for better identification. In bicycles, there is a limitation of placing the number plate either in horizontal direction by using a separate plate or in vertical direction by utilizing the mudguard area. Between these two systems a study was conducted to check whether a mudguard or an additional plate is better for numbering in bicycles. It was found that the existing number stickers used in campus are in various formats and poorly designed. The placement is not uniform and can be found in random places on the bicycles. The strength of campus' residence is more than seven thousand. Approximately 60% of the population use bicycle to commute inside the campus. Therefore, it was a demanding situation for design intervention to provide a uniform identification number which can be used to give uniform identity to all bicycles.

Through this paper an attempt has been made to design an ergonomically visible and aesthetically appealing numbering system which is readable and legible in both static and moving conditions.

2 Identification Number and Its Visual Design

The Vehicle Identification Number (VIN) usually consists of an alphanumeric code system, with a unique code used by a particular automotive industry and the governing system. There are certain criteria like the country code, model number of the vehicle, chassis number that is usually considered while VIN registration [4]. While studies of car number plate designs are oriented towards digital identification and their detection through algorithms, identification for bicycles has rarely been addressed. However, both car and bicycle share some common elements in the number plate and these elements are arranged in a visual hierarchy.

Visual hierarchy can be defined as arranging a group of visual elements according to their emphasis in the composition. Factors influencing the visual hierarchy of typeface are size, value, color, position, and proximity [2]. In a typographic composition, size, weight, color, and spatial interval are considered to create contrast and produce hierarchical arrangements [1]. Regarding the color composition of the number plate design it is found that the numbers in black color on white background are easily identified. Also, black colored foreground numbers on a yellow background are identified with 100% accuracy [3].

Fig. 1 Commonly used number plates and their positions. *Source* from *left to right* www.abc.net.au, www.activism.com, and www.farm3.staticflickr.com

Fig. 2 Different numbering system in IITG campus (from hand-painted to a pasted sticker)

Size of a design element in a graphic space and its size relationship with other elements in the composition contributes significantly in creating emphasis [5]. Figure 1 shows some existing number plate designs used across different countries. These designs differ contextually and according to the locales.

In the IITG campus, different numbering styles are used for numbering the bicycles posing difficulty to identify (Fig. 2). A sticker with IITG logo and pass number is also found in many bicycles (see last image in Fig. 2). However, all of these systems lack in effective identification and aesthetic value. Also, principles of visual hierarchy are not used in these examples.

3 Methodology

For the study, a survey was conducted with 25 people from each hostel to find out the important information he/she seeks in a number plate. It was found that the majority of users wanted to have IITG logo, hostel initials, and a unique number to identify their bicycles. Table 1 shows the user-preference of key elements in the number plate design.

After finalizing the key elements of the number plate, different designs were developed in both horizontal and vertical orientation including the modification of

Table 1 Preference by key elements in number plate design

Key elements	Yes	No	% Yes	% No
IITG logo	271	54	*83.38*	16.62
Hostel name	320	5	*98.46*	1.54
Roll number	65	260	20%	80%
Room number	77	248	23.69	76.31
Year of admission	147	178	45.23	54.76
Department (CSE/DD/HSS)	80	245	24.61	75.38
Course information (Ph.D./B.Tech/M.Tech)	37	288	11.38	88.61
Unique number	293	32	*90.15*	9.84

Italics are used to highlight the three most prefered elements by users in number plate design

Fig. 3 Different design layouts based on visual hierarchy

Table 2 Response for preferable number plate position

Preferred position	No. of respondents	Percentage
Rear mudguard	42	73.7
Front mudguard	10	17.5
Below the seat	5	8.8

present design. Different design alignments were explored in mudguard area. This study was done with the observational and experimental analysis of the design. The results are then compared with the existing number stickers and the data was tabulated (discussed in Sect. 4). Figure 3 shows the different design layouts used for initial experimentation.

It was found that instead of horizontal number plate, it is better to use the vertical mudguard area for numbering the bicycle. For the testing of the various designs, 57 respondents were taken. To select the representative bicycle, bicycles with a conventional mudguard were selected. Interviews were conducted with the security guards who specifically register all the cycles and also note the cycle numbers that are travelling in and out of the campus. Table 2 shows that 73.7% of the respondents preferred rear mudguard for placing the identification number followed by 17.5 and 8.8% preferring front mudguard and below the seat positions respectively.

4 Result and Proposed Design

After finalizing the position for placing the identification number, designs for testing were created using six typefaces. Table 3 shows the selected fonts with their unique characteristics which make them more readable and legible.

In the proposed design the vertical space of rear mudguard is used. The design is made using *Frutiger* typeface having larger x-height and aperture and suitable for distant reading. A font size of 60 points is suitable for reading from at least 8 m. The design area was 15 cm in length and 3.5 cm in breadth according to the mudguards used as samples. The study revealed that vertical numbering system on the mudguard area is most suitable. It was also found that numbering in top-down order is more legible and readable when bicycle is in motion as well as in static condition. Figure 4 shows the proposed design and its placement on bicycles for both male and females.

Table 4 consolidates the experiments and the results found after design exploration of different number plate designs. It was found that out of 57 participants, 84.2% of them found the proposed design to be more acceptable in the context of legibility, readability, and design aesthetics. Whereas only 15.8% of the participants found the existing design to be more appropriate.

Table 3 Different fonts used and their characteristics

Font name	Characteristics
Helvetica	Display font, larger *x*-height
Frutiger	*Good for distant reading, larger x-height, large aperture*
Arial	Most used typeface, curve is softer and fuller than most sans serif faces.
Georgia	Larger cap height, old style numerals with larger aperture and counter.
Times New Roman	Comparatively lower *x*-height and cap height but extensive use of typeface makes it easy to read.
Cambria	Larger *x*-height and close counter

Fig. 4 Final proposed design and its placement on bicycle

Table 4 Comparison between existing and proposed design

Design parameters	Response for existing design	Response for proposed design
Number of respondents (legibility)	9	48
Number of respondents (readability)	7	50
Number of respondents (aesthetically pleasing)	11	46
Total percentage of respondents (%)	15.8	84.2

5 Discussion and Limitations

This study was initiated with the motivation of applying graphic design principles in actual human working conditions. The current numbering system in IITG campus bicycles was found poorly designed as well as lacking any design aesthetics. The proposed design solution proves to be better in the aspects of design and ergonomic aspects. However, it should not be taken as a design solution for all the other bicycles used in different states or countries. As discussed in Sect. 2, that the number plate designs are context-specific; therefore the proposed design works appropriately in the IITG campus. Similarly, any other institutes with similar locale conditions might employ the proposed design.

With more modern design of bicycles appearing in the campus (few of them without a mudguard), the design was not tested on those models. Therefore, how the proposed design will work for them would take another study to make formulations. However, it would take a similar approach to design suitable number plates for those cycles as well as cycles with varying length of mudguards.

6 Conclusion

Visual ergonomics is an integral part of visual communication domain. It is clear from the study that one cannot neglect ergonomics factors in design where human interaction is involved. This study will be beneficial for the designers working with legibility and readability issues as well as for signage and way finding system designs. As our design works for both static and dynamic bicycles, this might provide for further ideas on developing signs in public spaces.

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Chapter 30
Anthropomorphic Televisions Are More Attractive: The Effect of Novelty

Anirban Chowdhury, Debkumar Chakrabarti and Sougata Karmakar

Abstract Literature suggests that anthropomorphic (humanlike) shapes in product appearance may be fruitful to design a product. However, anthropomorphism may have either positive or negative consequence in market. Novelty is an aesthetic dimension which may cause acceptance of an anthropomorphic product in market, due to attractiveness of the product. The present study was conducted to investigate whether anthropomorphic product appearance causes a high level of perceived novelty; thus, the higher level of perceived attractiveness and product choice. Results of the present study revealed that users perceived a higher level of novelty in product due to a higher level of anthropomorphism. It was also evident that users perceived the product as more attractive which had a higher level of novelty in appearance. Eyetracking study indicated that average fixation counts and fixation durations were higher in the case of television which had a higher level of novelty. Further, people choose the product (television) which had a higher level of novelty and attractiveness. Hence, novelty is the basis of making anthropomorphic product attractive and anthropomorphic product choice.

Keywords Anthropomorphism · Attractive · Eyetracking · Cognitive ergonomics · Product design

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1 Introduction

Novelty is a significant factor for acceptance of product in the market. Schoormans and Robben [1] suggested that the appearance of a product is the most prominent means to induce novelty. Due to change in the exterior appearance using humanlike shapes, possibly have some influence on product novelty perception. In addition, prior research has suggested that higher levels of design newness sometime may have a positive effect on consumers' evaluations of new products, and, sometime just the opposite to it [2]. Mugge and Dahl [2] defined design novelty (also referred to as newness or atypicality) as the deviation in a product design from the current design state of a certain product category.

Designers are adopting different strategies to bring novelty in product design [3]. Aggarwal and McGill [4] suggested that anthropomorphic (humanlike) shapes in product appearance may be fruitful to bring newness in product design. Visual attractiveness is another important criterion for the product choice [5, 6]. Novelty is sometimes related to attractiveness of the product [3]. In addition, if an anthropomorphic product is visually attractive then there is a chance of better product acceptance in the market [5, 6]. However, the humanlike attributes in product appearance are not always prolific to make product visually delight as anthropomorphism may have either positive or negative consequences [7].

Many reports suggested that eyetracking study is fruitful to measure attractiveness towards products [6, 7]. Scholars recently compared anthropomorphic car fronts with human faces based on people's eye movement patterns [8, 9]. Therefore, there was a high possibility to evaluate attractiveness of an anthropomorphic product using eye movement study. In addition, many authors suggested that fixation counts and fixation time are two important eye movement parameters which are correlated with attractiveness [7, 10]. Now, questions for the present research: What would be the effect of anthropomorphic product appearance on novelty perception? Will this novel product appearance make the product attractive? Does novelty due to anthropomorphic appearance affect product choice? To answer these research questions, the present study was conducted.

2 Study of the Effect of Anthropomorphic Appearance on Visual Attractiveness, Novelty, and Product Choice

The objectives of this study were to observe the effect of levels of anthropomorphism (in product appearance) on perception of novelty and visual attractiveness and to understand whether anthropomorphic product appearance positive or negative effect on product choice. Directional and causal alternative hypotheses for this study were as follows:

H$_a$: *Higher level of anthropomorphism causes significantly higher level of novelty in product appearance and thus it helps to improve visual attractiveness and product choice.*

2.1 Method

2.1.1 Stimuli Preparation

Literature suggested that a product can be anthropomorphised with addition of humanlike attributes into the product appearance [4]. Therefore, similar strategy was used to manipulate level of anthropomorphism in product appearance. A total of three televisions (see Fig. 1) were conceptualized and manipulated using humanlike attributes, to prepare television (TV) images with different levels of anthropomorphism (attribution of humanness). A strand was prepared like human legs in case of TV-1. The TV-2 had human hand like two sound boxes in addition to the humanlike feature of TV-1. In the design of TV-3, a round sound box was introduced in addition to humanlike attributes of TV-2. These three television images were selected as stimuli for the first phase of the present study. Two anthropomorphic televisions (TV-1 and TV-3) were selected after first phase of this study as these two televisions showed significant mean differences in perceived novelty ($p < 0.05$). For eyetracking study, a virtual shelf environment was created by placing these two television images on shelf. There were two stimuli with different placements of same televisions (see Fig. 2). All television images and virtual shelf environment were illustrated using Adobe Illustrator CS 4.

2.1.2 Participants, Measures and Procedure

This study was initiated with television design manipulation check. A total of 48 participants participated in stimulus manipulation check study (Age range = 17–

Fig. 1 Stimuli for anthropomorphism and novelty evaluations

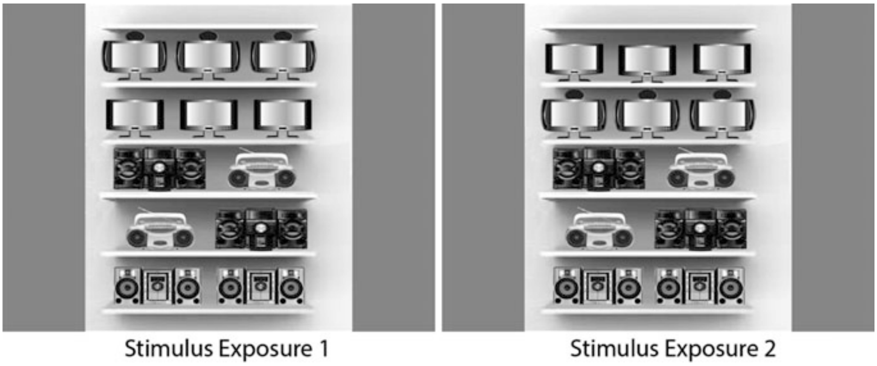

Fig. 2 Anthropomorphic televisions were placed in virtual shelf environment

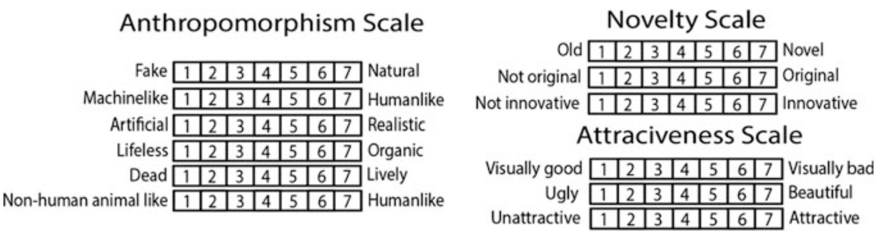

Fig. 3 Measurement scales for different variables considered under this study

35 years, $M_{age} = 23.85$, SD = 4.42, Female: 27.08%, Male: 72.92%). Stimuli manipulation check was done using a semantic differential (SD) scale for measuring the level of anthropomorphism (please see Fig. 3). For novelty check, a reliable SD scale was used to take responses from television users ($n = 250$, Age range = 20–35 years, $M_{age} = 23.97$, SD = 3.89, Female: 36.40%, Male: 63.60%). Novelty was measured by asking participants to rate the product appearance on three seven-point scale (please see Fig. 3) and items were adapted from Zhao et al. [11]. Reliability of the anthropomorphism ($\alpha = 0.81$) and novelty ($\alpha = 0.83$) scales were confirmed by calculating Cronbach's alpha values. The both scales were satisfied the minimum requirements of alpha value 0.70 [12].

In the second phase of this study, a total of 42 participants participated in the eyetracking study (Age range = 19–35 years, $M_{age} = 23.26$, $SD = 3.53$; Female: 43.12%, Male: 55.88%). Fixation counts and fixation time per area of interest were measured as visual attractiveness related measures in eye movement study. Responses for visual attractiveness were also taken using semantic differential scale (please see Fig. 3) from same television users. Among scale items, first item was self-introduced and last two items were taken from Hekkert et al. [13] and Page and Herr [14], respectively.

All participants were randomly assigned for this study and they were asked to rate anthropomorphism scale for three television images presented on computer screen in laboratory. On the other side, eye movements were recorded for each stimulus using SMI-iView-X-HED eyetracking system (50 Hz). Later on participants were asked to rate TV-1 and TV-3 on novelty and visual attractiveness scale. All participants were also asked to choose either 'TV-1' or 'TV-3' based on their preference.

3 Results

One-way ANOVA was conducted to check the status of stimuli manipulation. In ANOVA, the variation in a number of humanlike attributes was independent variable and the level of anthropomorphism was dependent variable. The results showed that the mean values of anthropomorphism were significantly varied with increment of number of humanlike attributes added to the television appearance [$M_{\text{TV-1}} = 4.07$, $SD_1 = 0.48$; $M_{\text{TV-2}} = 5.40$, $SD_2 = 0.88$; $M_{\text{TV-3}} = 5.56$, $SD_3 = 0.75$; F (2, 45) = 20.374; $p < 0.001$]. It was observed that mean value of anthropomorphism was highest in the case of TV-3 and lowest in the case of TV-1. Therefore, we decided to include images of TV-1 and TV-3 in novelty evaluation study. Independent sample *t*-test was conducted to observed differences in novelty perception due to anthropomorphism. Results indicated that mean value of novelty perception in case of TV-3 was significantly higher than the mean value of novelty for TV-1 [$M_{\text{TV-1}} = 3.55$, $SD_1 = 1.29$; $M_{\text{TV-3}} = 5.16$, $SD_3 = 1.15$; t (248) = −10.442; $p < 0.001$].

After repeated measure ANOVA, there were significant variations observed in mean fixation counts per AOI and mean fixation time per AOI due to the level of novelty reflected in television design ($p < 0.05$). Both the mean fixation count and mean fixation time were significantly higher in case of AOI fixed on TV-3 than the AOI fixed on TV-1 ($p < 0.05$). Within subject effect of the number of exposure of stimuli on mean fixation count and mean fixation time per AOI was also significant ($p < 0.05$). Mean fixation count [F (1, 82) = 18.368, $p < 0.001$] and mean fixation time [F (1, 82) = 40.854, $p < 0.001$] per AOI values were significantly lower in the first exposure, whereas, these values were higher in the second exposure.

Paired *t*-test was conducted to observe the differences in mean values of visual attractiveness between TV-1 and TV-3. It was found that mean value of visual attractiveness was significantly higher [t (41) = −6.189, $p < 0.001$] in the case of TV-3 ($M_{\text{TV3}} = 5.67$, $SE_3 = 0.11$) than the TV-1 ($M_{\text{TV1}} = 4.85$, $SE_1 = 0.09$).

It was observed from chi-square test that there was a significant difference in television choice [χ^2 (1) = 7.714, $p < 0.01$]. A total of 30 (71.43%) participants had chosen TV-3, whereas, only 12 (28.57%) participants had chosen TV-1. Therefore, TV-3 was preferred by maximum participants.

4 Discussion

Results suggested that the television which had a high level of anthropomorphism (due to more humanlike attributes) also had a higher level of novelty. Therefore, based on the study results, it can be inferred that anthropomorphism may be helpful to bring novelty in product appearance.

Higher mean values of fixation count/AOI and fixation time/AOI means that the AOI placed on object was more attractive. In addition, many authors reported that people are paying more attention if an object is more attractive [10]. Mean values of attention related eyetracking parameters (fixation count/AOI and fixation time/AOI) were significantly higher in the case of TV-3 than the TV-1. Hence, TV-3 was more attractive in nature. The questionnaire based visual attractiveness study also supported the same fact that TV-3 was significantly more attractive in compare to TV-1. Therefore, the results of both the questionnaire based attractiveness study and the eyetracking study were similar. According to Miesler et al. [15], anthropomorphism (e.g. babyfaceness) is related to attractiveness of a product. Now, it could be reasonable to argue that participants paid more attention to TV-3 as it was more attractive. Significantly more number of participants had chosen the 'TV-3' which means that people would like to choose the product having more anthropomorphic appearance. Maughan et al. [10] reported that people look more at the object which they like more. This might be the cause of getting the significant interactive effect of number of stimuli exposure and novelty level on variations of mean fixation count and mean fixation time per AOI. Participants paid more time in second exposure of a stimulus than the first exposure. Clement [16] reported that there is a relationship between visual attention with in-store buying decision. In the present study, there was a similarity between product choice and paid attention towards TV-3 which was revealed from the eyetracking study. Thus, the present study was able to explain the effect of novelty as a cause of television choice. Hence, hypothesis of the present study is supported by all these results.

It can be concluded from both the study findings that humanlike product appearance might be fruitful to bring novelty in product appearance; and, thus to make the product appearance more visually attractive and appealing to the consumers. Hence, the novelty is the reason to make anthropomorphic product attractive and anthropomorphic product (television) choice.

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Chapter 31
Identification of Aesthetically Favourable Interface Attributes for Better User Experience of Social Networking Application

Devyani Shirole, Anirban Chowdhury and Debayan Dhar

Abstract Different social networking applications commonly have different layouts which include different background colours, contact grid options, etc. Fewer studies have been taken into the account of user preferences of these attributes. In addition, aesthetics plays an important role in interface design acceptance of mobile applications especially in social networking domain. In corroboration with available literature, the present study was conducted to understand the users' preferences for various layout elements which include different background colours, contact list grids, contact details grids, and message reply buttons in social networking mobile applications, based on aesthetics perception. Results of the present study highlight that aesthetically pleasant layout attributes are beneficial for user acceptance of user interface of social networking applications. Based on present study results, an interface design guideline was developed to design interfaces for new and better mobile applications in the domain of social networking messenger.

Keywords Cognitive ergonomics · Design · HCI · Social networking · User experience

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1 Introduction

Social networking applications have become integral part of today's lifestyle. Millions of users are using these applications for their daily communications. All smart phone users are utilizing one or more of these social networking platforms to send or receive messages. The 'Pew Internet Project' reported that a total of 75% adults are using social networking applications [1]. A social network consists of different social actors who maintain relations and ties among them. As stated by Squires, young generations like to "integrate communication technologies, namely landline and mobile phone and instant messaging, with conventional face-to-face communication to form multimedia relationships" [2]. Impact of relationships can be distinguished into three relevant classes of relationships (human–machine relationships, interpersonal relationships between collocated persons, and machine-mediated human–human relationships) when the light of mobile communication is considered [3]. Among these relationships, a human–machine relationship is more important from user interface design perspective. Users' preferences of these applications depend on many factors. Veryzer identified that users' acceptance for a new product depends on customers' ability of understanding how the product works, aesthetics, and perception of its safety [4]. Aesthetics perception of user may be one of the crucial factors which may play an important role in social networking application selection as it was reported that users' choice of a product chiefly depends on aesthetics perception [5]. So it is better to go through a detailed literature survey to understand the probable impact of aesthetics on acceptance of user interface for social networking application.

2 Literature Review

2.1 Aesthetics in Mobile App and Websites

David demonstrated that aesthetics plays very important role in shaping responses of users to products and websites [6]. According to Bloch, Brunel, and Arnold, aesthetics is not just visual appeal but also the aspect of design which is most closely related to design, and issues of colour, shape, etc. [7].

It is reasonable to state that vision is the central channel for consumer/product relationships formation [8]. Reviews on most popular consumer electronic devices (e.g. iPhone™) disclosed the fact that the beauty of the design, intuitive visual interface are encroaching users' experience [9]. Previous research found that user satisfaction has affected by usability of the product, the result showed inherent usability was the main factor contributing to user's satisfaction [10]. It was also stated by Norman, apparent usability depends on the good appearance of the product [11]. Shenkman and Jonsson examined the users' first impression of websites and found that judgment of users was its beauty. It was observed that designers should consider both inherent usability and perceived usability by its aesthetic value [12]. Brady and Phillips observed that aesthetics has direct relationship on the usability of website [13]. It was revealed that “interface designers have to make efforts to make the interface “look” usable” [11, 14].

2.2 Roles of Aesthetics in UI Preference of Social Networking Applications

Visual aesthetics was found to enhance user experience positively. Lewis suggested that the social media acceptance and aesthetics have positive relationship [15]. Detailed research is required on the impact of visual aesthetics on accessibility on the mobile products [10]. Fogg et al. said that over 45% of consumers made judgments about the credibility of websites based on the design including layout, font and colour scheme [16]. Valdez et al. reported that there is direct relationship in colour selection and emotions. His study evident that the users rated purple-blue, purple, red-purple and blue-green as most pleasant hues, whereas, users rated green-yellow, blue-green and green as most arousing colours [17]. As per study made by Fogg et al., layouts play an important role in credibility of the applications [16]. Therefore, in present research aims to evaluate the users' preference of interfaces based on interface aesthetics in terms of colours, grids, contact lists, layouts.

3 Method

3.1 Participants

The present study was focused on smartphone users who are using social networking or instant messenger applications on their mobiles ($N = 40$; Male = 45.5%; Female = 57.5%). Their age ranges between 16 and 45 years. The user group included 10% house wives, 22.5% who worked in private sector, 2.5% in government sector and rest 65% participants were students.

3.2 Stimuli Preparation

In the first step, design attribute variations of existing layouts of different messenger applications, i.e. Facebook, WhatsApp, Contact+ and WeChat pointed out and few design features were isolated for the present study. The interfaces were designed with by isolating features from screenshots (using IPhone 5 with screen diagonal

Fig. 1 Social networking application layouts used as stimuli in this study. **a** Background colour variation. **b** Contact detail grid variation. **c** Message reply option variation. **d** Contacts list page grid variation

4 in.) of existing social networking layouts with variation of colours, contact list grids, contact details layout, reply page icon using Adobe Photoshop CS6.

It is observed that blue, green, purple and orange colours are popular amongst the messenger applications. The blue colour is extensively used in design as it is associated with the meaning communication [18]. The purple colour (which is very analogous to blue) is used by Yahoo, Viber. The green is used by WhatsApp, WeChat, etc., whereas orange is used by Bing, etc. Hence, in present study, green, orange and purple colours (orange—#faa032 (RGB: 250, 160, 50), green—#14c873 (RGB: 20, 200, 115) and purple—#a00064 (RGB: 160, 0, 100)) were used to observe user preferences of background colour (please see Fig. 1a). Three types of contact detail grid were used as stimuli in but layouts were different (please see Fig. 1b). Three types of layout designs were included for reply buttons in layout of send message page to create stimuli (please see Fig. 1c). Total three types of contact list grids were created (please see Fig. 1d).

3.3 Measures, Apparatus and Procedure

Participants were presented by questionnaire of 19 questions consisting of 3 demographics questions, 4 questions related to layout design preference and 12 items for aesthetics rating. Sony Vaio E series laptop (64-bit, Windows 8.1TM operating system, Intel(R) Core(TM) i3-3110 M processor, 240 GHz). System was used for stimuli presentation and collection of user responses. The screen size of the system was 15.6 in.; resolution: 1366 × 768; Colour depth was 32 bit, brightness 0, contrast 50 and gamma 1.0.

Users were asked to answer questions after observing the each screen layout carefully. Chi-square test was carried out to evaluate significant differences in user preferences and Friedman's ANOVA was conducted to observe variation, using the SPSS 20.0 software.

4 Results

4.1 Aesthetics Perception and Colour Preference

It was observed that significantly most of the people (50.0%) chosen the green coloured background for contact details page out of three colour variations [$\chi^2(2) = 12.35$, $p = 0.002$]. Orange and purple coloured backgrounds were second and least preferred colours respectively (please see Fig. 2a). Similarly, mean aesthetic rating was significantly higher for green coloured background [$\chi^2(2) = 15.42$; $p < 0.001$]. Mean aesthetic perception for orange and purple background were lower than green background (please see Fig. 2a).

4.2 Aesthetics Perception and Contact Details Grid Choice

Most of the people (47.5%) chose 'option-1' for contact details grid when colour was kept constant (green) and background was varied [$\chi^2(2) = 0.95$, $p = 0.62$]. Though user preference was higher in case of 'option-1' than the 'option-2' and 'option-3' but it was not significantly higher. Effect size analysis revealed that the tested effect size ($r = 0.15$) is relatively good. This means that there is a tendency of χ^2 test to be significant if the sample size is more. Similar to layout preferences, users also perceived 'option-1' as better that 'option-2' and 'option-3' but no

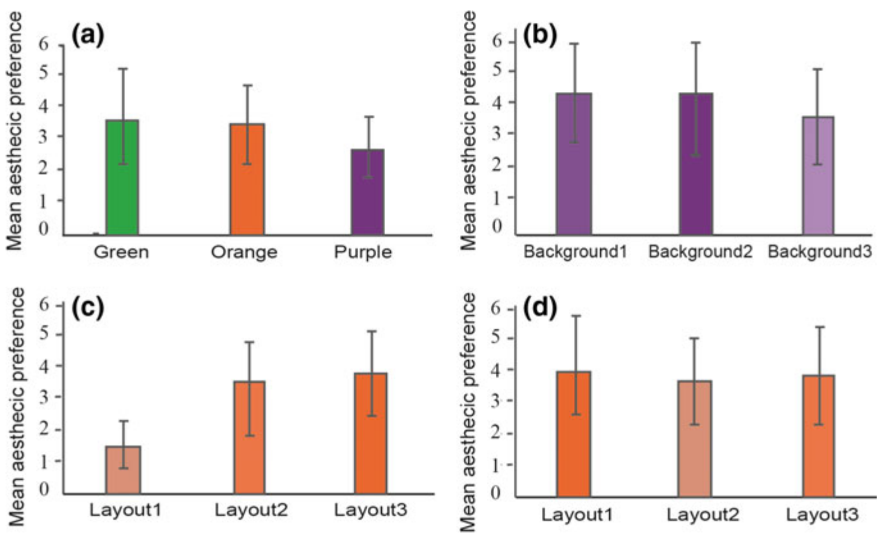

Fig. 2 Differences in mean values of perceived aesthetic preferences. **a** Contact detail page—colour variation. **b** Contact detail page—grid variation. **c** Reply page—reply option variation. **d** Contacts list—grid variation

significant variations in aesthetics perception was found after Friedman's ANOVA [$\chi^2(2) = 0.10$, $p = 0.94$, $r = 0.05$] (please see Fig. 2b).

4.3 Aesthetics Perception and Reply Button Icon

Significantly most of the people (60.0%) chosen layout 'Option-3' for message reply page while reply buttons were varied [$\chi^2(2) = 12.95$, $p = 0.002$]. The second preferred reply button was button of layout 'Option-2' and least preferred layout option was 'Option-1'. Reply button in page layout 'Option-3' was rated aesthetically more pleasant by smartphone users than reply button options in layout 'Option-2' and reply button 'Option-1' in page layout. In addition, reply button 'Option-3' in layout was also significantly more visually pleasant (aesthetically good) as perceived by users [$\chi^2(2) = 37.08$, $p < 0.001$].

4.4 Aesthetics Perception and Contacts List Grid

Significantly most of the people (62.5%) chose 'option 2' for contacts list grid layout style when colour was kept constant (orange) and page grid was varied ($\chi^2 = 15.35$, $p < 0.001$). Preference wise sequence of layout options in ascending order was Option-2 > Option 3 > Option-1. Contact list grid layout-1 was rated aesthetically less pleasant than the grid layout-2 and the grid layout-3 (please see Fig. 2). Contact list page layout-2 with was rated aesthetically most pleasant by users but no significant effect was observed in this regard.

5 Discussion

5.1 Colour Preference

It is observed from the study that green colour was most preferred background colour for contact details page and orange was the second preferred background colour. The probable reason of maximum acceptance of green background colour could be the users' psychological association with green colour. Further, green and its different shades were considered as arousing colour by maximum number people [17]. The green colour indicates natural, youthful, refreshment, etc. [19]. Since, most of the smartphone users are youth, they liked green background colour. Therefore, it can be argued that social networking application interface with green background colour would have greater acceptance by the users than the interfaces with orange or purple colour.

5.2 Contact Detail Grid Layout

It is observed that most of the smartphone users chosen the layout with circular small photo at the left hand corner (Option 1). This result indicates that the users find contact information such as phone number, email, etc. as more important than the photo of the contact person. Users might found this information is more usable than the photo. From the aesthetic ratings, it is revealed that same layout option is more aesthetically pleasant than the other two layouts (Option 2 and Option 3). It is well established that layouts play an important role in credibility of the websites [11]. Therefore, the layout presented as Option 1 in Fig. 2b, may be beneficial for designing new interface for social networking mobile application.

5.3 Reply Icon in Message Reply Page

From the observations, it is seen that users preferred layout-3 with reply icon than the material design like floating reply icon and the text based reply button. This result indicates that the users are very use to with iconic buttons as they are using such buttons in many mobile applications. Wiedenbeck highlighted that users preferred icons and icons with text over only text buttons [20]. Thus, users would like to see iconic reply button (please see Fig. 1c) much in a new design of social networking mobile application interface.

5.4 Contacts List Grids

It is observed that most of the people chosen contact list grid layout option 2 with display pic circular image at the left, name in right side and status on the right side than other two layout options (option 1 and option 3). This kind of result may be due to users' preference to see details of the person and his status in online along with the photo. Furthermore, image size was compact in contact list grid layout option 2. Similar findings was also observed by Chuang et al. when they studied users' preference for image sizes used in mobile phones. It was observed that users prefer compact images [21]. Therefore, it can be said that users would prefer contact list grid layout option 2 in the new interface design for social networking mobile application.

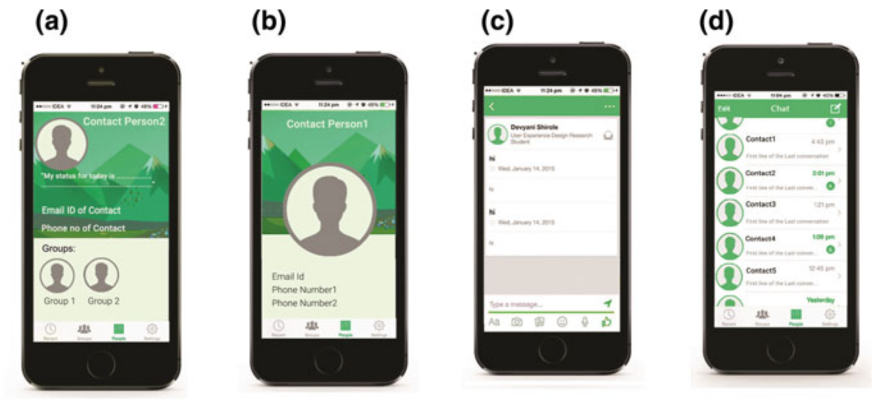

Fig. 3 Examples of interface layouts preferred by users: **a** Preferred background theme. **b** Preferred contact details. **c** Preferred reply option. **d** Preferred contact list grid

6 Conclusion

The result shows that it would be beneficial to design social networking mobile application interfaces as per the preference of the users. Examples of preferred layouts for social networking applications were presented in Fig. 3. There is more chance of users' acceptance if the new social networking mobile applications will be made considering this kind of the layouts. Use of these layouts would be desirable while designing a new social networking application for the age group of 16–45 years of age for both male as well as female group of users. Users including students, private sector employee, house wives, government employees, etc., would like to use applications designed with these layouts.

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Chapter 32
Exploring Embedded Intelligence as a Means of Minimizing Cognitive Load of Students in Electronics Engineering Instructional Laboratory Sessions

Anmol Srivastava and Pradeep Yammiyavar

Abstract Laboratory courses form an integral part of electrical and electronic engineering curriculum necessary for equipping students with skills and ability to solve problems in real-world contexts. However, students often feel frustrated and demotivated while conducting certain experiments in laboratories due to hindrances like inability to debug circuits and lack of theoretical and practical knowledge. Students often come unprepared to the time-bound laboratory assignments with insufficient pre-reading and sometimes require continuous assistance from their instructors to perform the experiments in practical laboratory sessions. This paper presents an initial stage in developing heuristics for embedding intelligence into electronics engineering laboratory-based learning artefacts in a pervasive and ubiquitous computing scenario. Such artefacts can be tools and equipment like breadboards, voltmeter, digital power supply, etc., used in laboratories. An empirical study was conducted to understand the type of intelligence needed to be embedded into such objects in context of electrical and electronic engineering laboratories to improve learning experience of students by minimizing their cognitive load. Data was collated qualitatively from studies involving student feedbacks. Semi-structured interviews of undergraduate students and subject matter experts (SMEs) were carried out. Based on the study and data analysis, potential areas where interventions can be made have been identified and presented in this paper. Their potential to become a basis of formulating and embedding intelligence in the next stage is outlined.

Keywords Education · Embedded intelligence · Laboratory · Ubiquitous computing · Experiential learning · User-centered design

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1 Introduction

Students involved in performing practical experiments in electronics hardware laboratories often get frustrated due to faulty equipment, troubleshooting problem or unable to understand the procedures as prescribed in a lab manual or by a lab instructor. This impedes their learning flow [1]. Most of the time the experiments are performed on trial and error basis by the students which reduces the 'learning' component—the very purpose of the experiment being part of a prescribed curriculum. Further, given the limited amount of time in which these experiments are to be performed within a fixed time table slot, students' motivation is mostly hinged on getting over with the ritual rather than learning. A possible solution is to embed instructions within the hardware. Toward achieving this objective the first step is to understand the factors leading up to the dissatisfaction stage starting with identification of the factors.

This paper attempts to report the identified factors leading up to cognitive load experienced by students while performing experiments in electronic engineering instructional laboratories. Eliminating such factors can shift the attention of students from performance-based approach to a desirable learning-based approach while conducting laboratory exercises.

The authors posit that by embedding intelligence into laboratory equipment and tools like measuring instruments, breadboards, etc., so as to eliminate such cognitive loads, learning practices can be made more efficient and effective for the students. Such a scenario is envisioned for classroom of tomorrow where ubiquitous learning environments will prevail. In future paradigm, computing and processing will be embedded into mundane objects to make them smart or intelligent objects. When such objects get interconnected they would form the Internet of things (IOT). Since, the context of the study reported in this paper is based on educational environment, such objects are referred as 'tangible smart learning objects'. Studies on the use of emerging technologies for education [2, 3] indicate that although at their initial stages, these technologies will play a crucial role in shaping education in near future.

2 Background Study

Study [4] on role of undergraduate laboratories discusses about their usefulness and present future directions for making learning in laboratories effective. Suggestions include defining clear objectives to students for performing experiments and demonstration of the same. The study also indicates a need for introduction of novel technologies in laboratories and to provide a framework for improving current laboratory practices. Research study [1] reports that around 78% students felt frustrated due to improper laboratory manuals and trouble shooting of equipment.

Findings from [5, 6] indicate that it is also important to consider factors such as students' situational interest, understanding, and degree of boredom to account for transformative learning process.

When looking at studies in the field of smart objects [7] as a medium for learning, posits have been made that such technology can increase the efficiency and concentration of students by distributing their workload. A conceptual scenario was presented in [8] depicting the use of smart objects to detect the user context by measuring certain physiological and psychological parameters. Research studies [9, 10] indicate how smart objects can provide richer learning experience by providing intelligent feedbacks.

The above literature survey reveals that most of the studies in the field of smart objects present only conceptual application scenarios. Considering the context of educational laboratories, it is important to consider factors which can contribute toward embedding of intelligence into such objects to reduce frustration and increase interest of students. Hence, the following study investigates factors of cognitive load experienced by students. By accounting for reduction of such factors while embedding intelligence into laboratory tools and equipment—using sensors and microcontrollers, it is posited that learning experience can become richer and more effective.

3 Methodology

A group of users were involved in an information collection survey. The sample universe consisted of second-year undergraduate students of electrical and electronic engineering program and subject matter experts. Data collection techniques included observational study, field notes, photographs, videos and audio recordings. The Subject Matter Experts (SMEs) were two professors of electrical engineering branch who conducted the laboratory for these students.

Observations and video recordings were made for 15 students (n = 15) performing experiments in electronic circuits and devices laboratory, refer Fig. 1. Each group consisted of three students. Semi-structured interviews of 20 students

Fig. 1 Screenshots of video recordings while observing students conducting practical experiment in electronics instructional laboratory

(n = 20) and two subject matter experts were conducted and recorded. The interviews aimed at understanding various aspects that hinder with students' learning in laboratories while conducting practical experiment.

The video and audio recordings were analyzed and various factors of cognitive load while performing practical experiments in labs were identified. The videos were analyzed using the process of interaction analysis and audio recordings were analyzed using content analysis after transcribing.

Based on the analysis, a cognitive demand table, refer Table 1, was constructed using Applied Cognitive Task Analysis (ACTA) methodology as mentioned in the literature [11]. Table 2 highlight a few responses of students from the interview. It was also observed that students related the complexity of circuit to the amount of time it took to perform the experiment. The more time it took to execute an experiment, higher frustration levels were reported. They also complained about the shortage of time felt in laboratories for conducting and performing some experiments. Students attested that it is very important to have instructors in laboratory to help and teach them. Most of them reported that they also take help from Internet to obtain information regarding various experiments.

Upon interviewing the SMEs, it was revealed that they are often unable to attend to all students owing to large class size. It was also highlighted that having complicated circuits, with many wired connections, becomes cumbersome for both instructors as well as students. Table 3 highlights a few responses of the SMEs.

Table 1 Cognitive demand table of undergraduate electronics laboratory

Difficult cognitive element	Why difficult?	Shortcomings identified
Instructions and procedures	Improper instructions create difficulty in understanding	Insufficient theory and precautionary measures
Faulty equipment	Causes frustration and consumes time as debugging becomes difficult	Fault in breadboards, digital multimeters
Complicated circuit	Cumbersome to rig circuits and time consuming	Difficult to trace errors, large wire connections, wrong placement of electronic components
Lack of equipment knowledge	Leads to cluelessness. Unable to validate results	Not able to troubleshoot misaligned settings
Time constraints	Allotted time falls short for large experiments. Attention shifts on completion rather than learning	Focus on experiment completion
Debugging of circuit	Trial and error based debugging. Causes frustration. Consumes time	Try all possible ways to debug the error

Table 2 Response of two students regarding laboratory experience

Participant	Response
Student 1	"Large circuits consume a lot of time as there are many wired connections. But after implementing them, we feel excited…"
Student 2	"We mostly use trial and error method to find faults in the implemented circuit… sometimes we have to unrig the whole circuit…"

Table 3 Response of two subject matter experts regarding laboratory experience

Participant	Response
Expert 1	"…it would be better if excessive wires could somehow be reduce, it will help in performing the experiment…"
Expert 2	"…sometimes it becomes difficult to explain each student in a large class while they are performing the experiment…"

4 Inferences

The study indicates that current practices of learning in laboratory are oriented more towards performance instead of learning. These are several factors that contribute to the cognitive load of a learning student. Students when working with various tools to learn or develop skills and concepts, often exert a lot of effort and time in trying to first understand how the tool works and then get down to the actual learning matter. This often leads to frustration and lack of motivation in students. It was also observed that students often compared complexity of circuit to the time taken to perform the experiment. The students also stated that time-consuming experiments —especially those which are difficult to assemble on breadboards or whose output upon completion of assembly takes time, sometimes lead to frustration and demotivation. Further, time can be identified as a crucial factor and marker for students in this learning process. Based on these observations it can further be hypothesized that:

$$\text{Complexity of Circuits} \propto \text{Time to perform the experiment} \tag{1}$$

The study also indicates that factors such as trial and error based and insightful learning come into play when students perform laboratory exercise. Understanding how knowledge formation and learning how happens in this situation is also important.

5 Conclusion

When considered from the viewpoint of embedding intelligence into laboratory equipment and objects—by using various sensors and microcontrollers, eliminating factors of cognitive load, as identified in this study, can improve the performance and learning of students in instructional laboratories. However, such factors contribute to only first degree of embedding intelligence into tangible smart learning objects. Further investigations are required to enquire about means and modes of effective communication of objectives and instructions to students using emerging technologies such as augmented reality. These can be used in conjunction with tangible smart learning objects to enrich the overall instructional laboratory learning experience.

Acknowledgements We are thankful to all the students and teachers, who became a part of our study. We would also like to state that due consent was taken to record videos and photographs.

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Chapter 33
Product Graphical User Interfaces: A Study for the Meaning and Usability on Automobile Dashboard User Interfaces in Indian Context

Venkateshwarlu Varala and Pradeep Yammiyavar

Abstract Product graphical user interfaces are the portals for the human–machine interaction. In our day-to-day lives, we come across several products with graphical user interfaces as the way to interact with them. These interfaces are designed to serve the several user groups across the globe. While the purpose is to communicate the meaning in the best way possible and creating a bond with their users, yet we see many interfaces irritate us at some point of time and become ambiguous to operate. There could be several reasons for such experiences. Through the product semantic studies and an experiment on different Indian user groups this paper tried to explore the meaning related issues, usability problems of automobile dashboard interfaces in the Indian scenario.

Keywords Product semantics · Semiotics · Meaning · Usability · Graphical user interface

1 Introduction

Product Interfaces of tangible products serves as a communication bridge between products and the user. They evoke meanings in users in a way they understand, and thereby creating a successful interaction, creating a bond [1]. To design a meaningful interface, designers make use of different features and attributes of the product [2]. For instance in a tangible product interface, a switch to turn on/off with specific color, a handle to hold with different shape, and in case of a graphical user interfaces a set of metaphors and visual cues are used in two dimensional space.

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Studies indicate that semantics of visual cues and metaphors vary across strata, within cultural groups and may have a contributing role in communicating the meaning, increasing the bond between a user and utility value of a particular group. While the purpose of any graphical user interface to convey the meaning, yet there are many graphical user interfaces (GUI) of various products in the Indian market which are failing in this regard. A pilot study conducted with existing electricity meters among various Indian users reveals that the users find them ambiguous and most of the information does not make any sense to them and less usable. In light of literature, it is suspected that the possible reasons might be disconnects between the intended and evoked meanings due to the non-consideration of cultural and contextual usage variation of various user groups, and lack of GUI design heuristics for various Indian contexts. A further literature survey followed by an experiment was conducted to know the reasons for failure of GUIs in communicate the meaning and its effect on the usability.

2 Literature

According to theory of communication, meaning in linguistics is an expression by a sentence and evokes a sense of understanding to its receiver at a given context [2]. Likewise the sentence, artifacts propagate meaning through different attributes. Product semantics [3] is a theory developed by Krippenderf and Butter which talks about meanings in artifacts. They define product semantics as a study of meaning in artifacts, a methodology and language of how artifacts attain the meanings for their users and how users attribute the meaning to them in a given context at different levels.

Meanings are manifested in different ways and at various levels such as, explicit meaning, implicit meaning. Implicit meanings are the one deeply embedded in products and communicated by evoking the emotions and sentiments [1] of personal or cultural group. A product can make a sense and invoke a meaning only when the product attributes are affecting the user. Gibson [4] calls it as the affordance. Affordances of any object are greatly influenced by the way one perceive it and ultimately affecting the meaning invoked.

It is known from cognitive sciences that meaning making is a cognitive activity and it starts with perception. Literature [5] in this field says that perception is greatly influenced by the factors such as user cultural background, context of use, emotions, and sentiments. For example in Chinese culture the color red is more of auspicious sign than the sign of danger.

Psychology researchers Lohani et al. [6] in their study on multicultural affective response highlights that there are slight cultural variations which would impact the way Europeans perceive the information as compared to the Indians.

From works of Crilly [7], Karjalainen [8]. Who argues this disconnect with different names highlight the mismatch between intended meanings and the evoked meanings. Literature from the cognitive sciences suggests that this disconnect could be due to the absence of incorporating the cultural, contextual seams in the design process.

The existing design process and semiotic guidelines [9] for interface design suggested by various researchers is more of technical in nature which emphasize on semiotic construction of individual elements but not as how this individual elements as a whole acquire a meaning in someone's day-to-day activities, and there are no specific guidelines about how culture and context effects the meaning and usability of the interfaces. Literature survey finds gaps as how these things are being addressed in Indian scenario and lack of heuristics for designing interfaces for Indian users and seams that need to be incorporated as part of GUI's so as to enhance the products value.

The experiment designed and conducted to know the reasons for failure of GUIs in communicating the meaning in Indian scenario and its effect on the usability.

3 Experiment

3.1 Method

3.1.1 Subjects

Seven participants of an age group of 20–60 years participated in the experiment. Subjects are from the different parts of India. The criteria for the participants are Indians with minimal experience with GUI-based Products or Automobile dashboard Interfaces.

3.1.2 Stimuli

For the experimental study, five automobile dashboards interfaces of various cars currently running on Indian roads were chosen. Dashboards were photographed for 3D and 2D with a high-resolution camera and 5 sets of stimulus were prepared in 3D, 2D formats (shown in Fig. 1). Stimulus was presented to the participant in two ways, one as 3 dimension stimuli through the smartphones-based 3D virtual reality headset and second stimulus as 2D picture for eye moment recording and open-ended question. Graphic symbols of various dashboard cluster controls of test dash boards were also collected for symbolic meaning related questionnaire. All the dashboard symbols that are in current use are complied with ISO: 2575:2010 standard.

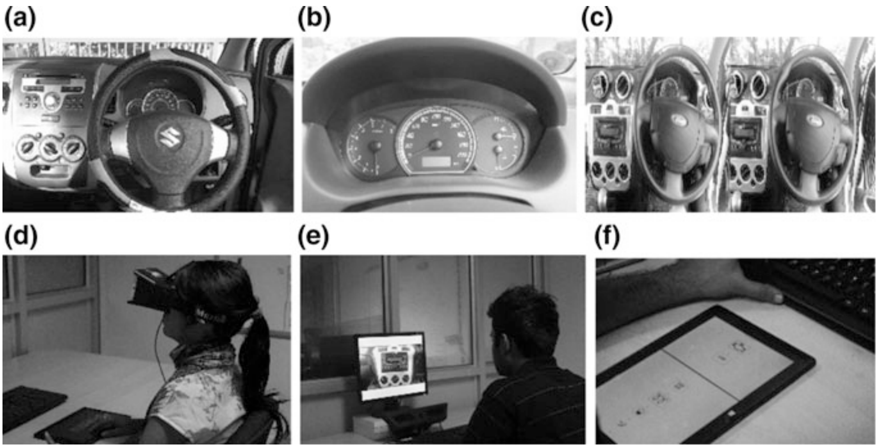

Fig. 1 Experimental stimulus, procedure in sequence. **a**, **b** Sample 2D stimulus, **c** sample 3D stimulus, **d**, **e** 3D and 2D stimulus presentation, **f** dashboard symbols

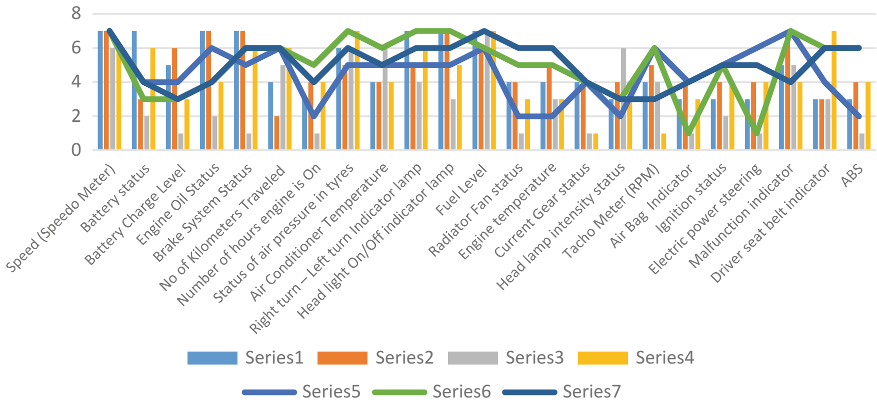

Fig. 2 Graph showing the trends of meaning variations

3.2 *Materials and Experiment Procedure*

Experiment was conducted in a laboratory environment equipped with the tools required.

Step 1: Subjects were first sensitized with the 3D stimuli (Fig. 1) of test dashboards with the help of smartphones-based 3D virtual reality headset to recreate the real-time environment. Then proceed for eye movement recording.

Step 2: Each subject was presented with sets of 2D photographs of the test dashboards on a monitor for the eye movement recording (EMR).

Step 3: Responses for Pre-designed Questionnaire which include questions based on semantic differential scales, usability engineering were collected after EMR recordings.

Step 4: ISO: 2575:2010 standard symbol set collected from the car user manuals were presented for symbolic meaning related questions.

4 Results and Discussions

Experiment is conducted with 7 subjects with an average data collection time of 5400 s (90 min) per subject. This experiment is a part of ongoing research and more data with large sample size is expected in near future. Trends of results analyzed from the 7 subjects are presented in this paper. Trends of the results are in favor of posits proposed.

A relative visual comparison between subjects of eye moment recording (Fig. 3) data shows considerable variations between urban users and rural users. From the questionnaire data (Fig. 2) considerable differences were observed as how a rural user is perceiving the dashboard as compared to the urban user.

From the symbolic meaning retrieval data which is partly qualitative, it is observed that most of the users failed to recall the meaning of the symbols which means the trying to adopt to the symbolic conventions than they are being naturally understood and for some users they makes no sense at all.

Fig. 3 Eye movement recording data differences between urban and rural users, **a**, **b** urban users, **c** rural users

5 Conclusion

Analysis has found that the interface designs are rational, semiotic in nature, and comply with international standards but they lack meaning in the various Indian contextual scenarios and forces the users to adapt to the products which is not very user centric. Hence, the Study finds a need for design heuristics for designing user interfaces addressing contextual issues in Indian scenarios and yet complying with international standards.

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Chapter 34
Effect of Baby-Like Product Personality on Visually Perceived Pleasure: A Study on Coffeemakers

Prachi Karkun, Anirban Chowdhury and Debayan Dhar

Abstract There is more chance of product acceptance if consumers perceived a product more pleasurable. It is evident that certain product personality can make product pleasurable. Therefore, present study aims to discover the effect of a baby-like personality of electronic product (coffeemaker) on user's perceived pleasure. The current study employed two separate experiments to measure product personality and users' perceived pleasure respectively. First experiment described about the personality evaluation of coffeemakers which had different appearances; whereas, in the second experiment, users' perceived pleasure was evaluated. It was observed from the results of the first experiment that baby-like personality perceptions depend on appearances of coffeemakers. In addition, users perceived the coffeemaker more pleasurable due to higher degree of baby-like personality. Thus, it can be envisaged that baby schema effect may be used for enhancement of product choice as consumers felt pleasure due to baby-like product personality.

Keywords Cognitive ergonomics · Emotion · Perception · Product personality · Design

1 Introduction

Rapid technological advancements open a wide arena of opportunities for product designers to provide innovative design solutions to customers. Such scenarios create a highly competitive environment in product industry; designers need to think

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beyond like functionality, performance, usability, etc., and they to identify special characteristics of the product that influence product choice by consumers. During a product's evaluation through visual channel, the product is judged majorly on the basis of its shape, form, i.e., its appearance. Therefore, a consumer's perception towards a product is mainly influenced by its appearance and aesthetics [1]. It is worthy to mention here that positive emotion such as visually perceived pleasure is related to product aesthetics [1]. On the other side, people have a tendency to associate a human like personality to product appearance. Therefore, each product is said to possess personality like human beings, and product personality may play a crucial role in determining customer's attitude towards a product [2, 3]. Product personality can be defined as set of human-like attributes displayed by products based on their appearance [4]. Hence, in order to have an advantage of a customer's loyalty, anthropomorphic forms in products play an important role. Anthropomorphic products are those which have a human-like appearance [5]. Studies related to anthropomorphic products have majorly investigated self-congruency effect. Self-congruency effect suggests that consumers experience has stronger attachments to products which are congruent to their own personality [6]. It has been established in related studies that anthropomorphic products are not only considered for purchasing, but are considered for a lifetime attachment by consumers. Product attachment results in a longer usage period due development of emotional bond between a human and the product [7]. Thus, there have been numerous efforts to produce emotions through anthropomorphic features of products [5]. Product pleasure is defined as emotional, hedonic, and practical benefits associated with product [8]. Products that are perceived to possess pleasurable characteristics are preferred more by the consumers [8]. Product attributes that are able to evoke pleasurable emotions will have advantage of product's acceptance in market [9].

Kindchenschema' (baby schema), is described as configuration of perceptual features found in newborns across species, which can be a high, slightly bulging forehead, large eyes, and rounded cheeks [10]. Infants are said to automatically grab attention, carefulness, and caretaking behavior and protection of adults [10]. As suggested that like humans, cuteness in products can be due to its anthropomorphized features [11]. The baby schema particularly baby-like face is correlated with positive attributions such as cuteness, warmth, fondness, and honesty [12]. 'Kindchenschema' related studies are generally oriented towards investigating its effect on human attention, and behavior. Researches related to anthropomorphic product designs have been able to investigate the affective response of human towards cute products [13]. However, there are limited studies that investigate the effect of baby-like personality on perceived pleasure. Literature suggested that happiness being an attribute of perceived pleasure [14]. Therefore, the present study aims to observe the effect of baby-like product personality on visually perceived pleasure. Therefore, the following hypothesis was stated according to the aim:

H_a: Visually perceived pleasure of users is significantly different due to different degrees of baby-like product personalities.

To prove this hypothesis methodically, two working hypotheses were coined and each hypothesis was proved in following two experiments.

2 Experimental Study

In the first experiment a set of coffeemaker images were evaluated with an intention to observe differences in baby-like personalities due to product appearance. On the other side, in the second experiment, the coffeemaker images were evaluated with an intention to observe differences in perceived pleasure due to product appearance. Two working hypotheses were stated based on objectives which are as follows:

$\mathbf{H_{a1}}$: Perception of baby-like product personality of users is significantly different due to different product appearances.
$\mathbf{H_{a2}}$: Users' perceived pleasure is significantly different due to different product appearances.

2.1 Stimuli

Literatures have suggested product personality effect on users purchase intention. Studies were primarily oriented towards products like cars, clocks, and chairs, etc. [15, 16]. Similar studies related to electronic products are very limited. There are certain electronic products that are used in daily basis. Considering the growing trend of coffee culture in India, the present study intends to investigate the effect of baby-like personality of coffeemakers on the visually perceived pleasure. Five postgraduate product design students of MIT Institute of Design (Pune) were assigned for the selection of coffeemaker images. Each student was supposed to select one gray-scale image of coffeemaker that best represented baby-like appearance. A total of five gray-scale images were the selected as stimuli for the present study (please see Fig. 1). Literature suggests that perception of product personality varies with product appearances [3, 7, 17]. In present study, it was expected that perception of degree of baby-like personality of coffeemakers and visually perceive pleasure of consumers might vary with coffeemaker appearances.

2.2 Participants

A total of 14 participants (male: 6 and female: 8) were randomly assigned in the first experiment. All participants were between age group of 22–35 years, with average age of 26 years. All participants were user of coffeemakers. A total of 19 participants (male: 12 females: 7) participated in the study. In the second experiment, all participants were between age group of 22–40 years, with average age of 28 years. All participants were users of coffeemaker.

Fig. 1 Coffeemaker images selected as stimuli

2.3 Measures and Procedure

A standard visual sematic scale was employed to measure baby-like personality of coffeemakers. This scale includes following adjectives related to baby-like personalities—'Cheerful', 'Lively', 'Cute', 'Honest', 'Modest' [4]. According to Mugge et al. [4], these scales were reliable. All these items were included into a questionnaire for present study.

A standard visual sematic scale was employed to measure perceived pleasure of coffeemakers This scale includes following adjectives related to perceived pleasure—'satisfaction, 'happy', 'pleasant' [14]. Reliability of perceived pleasure scale was verified by calculating 'Cronbach's alpha (α) value. It was found that the scale was reliable as the calculated alpha value (0.89) was greater than 0.70.

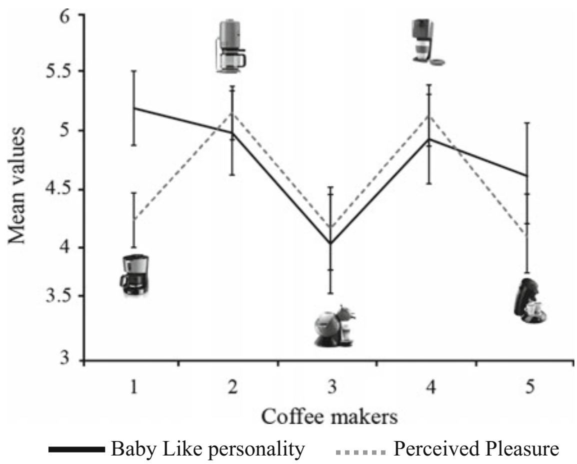
The questionnaire containing seven points visual semantic scale was developed online using 'Google form' application. This questionnaire was distributed to the participants through mail. Each participant had to view the given stimuli (Fig. 1) one by one and rate them on baby-like personality scale and pleasure scale.

2.4 Results and Discussions

As the sample distribution pattern was not following the parametric distribution pattern (normality testing data not presented), 'Friedmann ANOVA' Test was conducted to observe mean variations of baby-like personality due to different coffeemaker appearances. The analysis of the results was conducted using SPSS 20.0 tool. Results from the test suggested that there is significant mean variation in baby-like personality among coffeemakers due to their appearances [χ^2 (4) = 18.849; p = 0.001] and supported $\mathbf{H_{a1}}$. Then, a multiple comparison test (Wilcoxon test) was conducted for pairwise comparison. Wilcoxon test suggested that significant difference in values of baby-like personality also existed in pairs of coffeemakers. These pairs are:—coffeemaker—2 and coffeemaker—1 ($Z = -3.000$; $p < 0.05$), coffeemaker 3 and coffeemaker—2 ($Z = -2.555$; $p < 0.05$), coffeemaker—5 and Coffeemaker—2 ($Z = -2.729$; $p < 0.05$), coffeemaker—4 and coffeemaker—1 ($Z = -2.767$; $p < 0.05$), coffeemaker—5 and coffeemaker—4 ($Z = -3.206$; $p < 0.05$). It was observed that coffeemaker—2 possessed maximum level of baby-like personality (please see Fig. 2). Results from experiment supported the existing theory of baby schema. Coffeemaker—2 had highest level of baby-like personality as the coffeemaker had an upper part similar to bulky baby-like head, simple and curvilinear form, and representing cheerfulness. In addition, baby-like personality also goes with cute appearance of the product [18, 19]. As per the results, coffeemaker—3 was perceived to have a less baby-like personality. This might be due to the complexity in shape, unsymmetrical form, and bulkiness of body in case of coffeemaker—3.

'Friedmann ANOVA' was also conducted to observe mean variations in perceived pleasure among coffeemakers. Results suggested that there were significant mean variations [χ^2 (4) = 10.649, $p < 0.05$] in perceived pleasure due to product appearance and supported $\mathbf{H_{a2}}$. Since, it has been established that baby-like personality traits like cheerful, cute, honest modest, etc., influence positive emotions [4] and the perceive pleasure is a positive emotion [14]. Present study also revealed the similar fact. The multiple comparison test (Wilcoxon test) suggested that significant difference existed between pairs of coffeemakers. These pairs were coffeemaker—1

Fig. 2 Mean personality and pleasure variations of coffeemakers



and coffeemaker—3 ($Z = -3.514$; $p < 0.05$), coffeemaker—2 and coffeemaker—3 ($Z = -2.587$; $p < 0.05$), Coffeemaker—2 and coffeemaker—4 ($Z = —2.562$; $p < 0.05$). It was observed that coffeemaker—1 was perceived to be most pleasurable followed by coffeemaker—2, coffeemaker—4, coffeemaker—5, and coffeemaker—3. There was an unexpected result in case of coffeemaker—1, to which users perceived highest level of pleasure.

3 Summary and Conclusion

The present study revealed that baby-like personality traits (cheerful, cute, honest, modest, and lively) have potential of evoking pleasure among users. Thus, baby schema helps to increase the market acceptance of the product as it is already established that positive emotion has positive effect on product acceptance [1, 19]. The graphical plot of mean values for baby-like personality against perceived pleasure suggested that, with variations in baby-like personality, the perceived pleasure of participants varied for coffeemakers 2, 3, and 4 (Fig. 2). However, for coffeemakers 1 and 5 the baby-like personality effect on perceived pleasure was opposite. This discrepancy in results may be due to limited number of participation in the studies. Hence, the main hypothesis of current study (i.e., 'perception of baby-like product personality of users is significantly different due to different product appearances') is proved partly. It is envisaged that present study may act as guideline for designers and human factor experts to propose effective design solutions for pleasurable products that possess baby-like personality.

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Chapter 35
'Quantitative Probabilistic Widgets': Method to Improve Usability Performance of Data Entry Task

Shrikant Salve and Pradeep Yammiyavar

Abstract This study focuses on data entry work done by operators working at Rural BPOs in India. It challenging to maintain the data quality while data entry. Therefore, to improve the data quality challenges, this paper introduces user interface involving data entry widgets based on quantitative probability. We hypothesize that, 'quantitative probabilistic widgets' improve performance of data entry. To prove this, we have conducted an experiment involving ninety five participants belonging to the age group of 18–30 years working in Rural BPOs of Maharashtra, a state situated at western side of India. The user interface was specially designed for this experiment. This interface uses different fields/widgets involving several specially designed widgets used during data entry. The task for experiment consists of transcription of given paper form into electronic form using both interfaces (existing and designed). The computer based background recording of each participant interaction with both user interfaces have taken for the calculation of accuracy and speed. There are significant differences in the speed of the entry and slight difference in error rate for two experimental conditions for the data entry. The results of this paper indicate that probabilistic approach can be used to design intelligent user interfaces for data entry which help to improve data quality.

Keywords Quantitative probabilistic widgets · Rural BPO · Data entry · Usability

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1 Introduction

Rural-Business Process Outsourcing (R-BPO) is one of the few avenues of employment for rural India. Typical services offered by Rural BPOs include data-based and voice-based services [9]. The data-based services involve digitization services, data entry, converting document to different format and many more. This study focuses on data entry. There are many challenges for data entry like lack of expertise in design of paper to electronic form, the transcription process (paper to digital) for double entry is costly and time consuming, and poor quality of mobile data entry [1, 7, 8]. Therefore, to overcome above issues and improve the data quality challenges, this paper introduces user interface involving data entry widgets based on quantitative probability [3]. The data entry techniques can be improved by use of machine learning, to investigate this we have conducted literature survey stated in next section.

2 Literature

This paper work builds on several areas of related work from the literature on improving data quality during entry. Kleinman [5] has stated the adaptive method for double data entry based on probabilistic approach. This technique calculates the probability of each form based on lagged set of most recently double data entered forms. The simulation shows that much of the re-entry can be avoided by detecting many errors. This study gives rise to development of the probabilistic approach for the data entry. Chan et al. [2] have proposed an end to end system (named as *USHER*) for form design, entry and data quality assurance. *USHER* learns a probabilistic model over the questions of the form using previous form submissions. Then it applies this model at every step of the data entry process so as to improve the data entry quality. Before the entry *USHER* induces a form layout that captures the most important data values of a form instance. Once *USHER* has been learned, it dynamically adapts the form to the values being entered and enables the real-time feedback to guide the data entry operators toward their intended values. Their results demonstrate considerable improvement in data quality for each component/widget compare to existing practice. Lee et al. [6] have implemented intelligent data entry assistant (called as *SmartXAutofill*) for predicting and automating inputs during entry for XML document. *SmartXAutofill* consists of multiple internal classification algorithm integrated into an ensemble classifier to form single architecture. Each internal classifier uses approximate techniques to propose a value for an empty XML field and through voting the ensemble classifier determines which value to accept. *SmartXAutofill* system was evaluated using data from eleven different XML domains. This study is limited to XML document domains only.

The machine learning tools can used to assist repetitive form filling tasks by providing default values for particular section of the form, which thereby reduces the number of keystrokes necessary to complete a form and also reduces risk of errors [4]. Hermens et al. [4] have developed the user interface (learning apprentice) for repetitive form filling task of ‘leave report form’. The authors evaluated the efficiency of this system by measuring keystroke error and prediction errors observed during typing. The results indicate that their method (ID4) reduces number of keystrokes required by 87% compare to non-learning methods. Another empirical study was conducted in [11] by Warren to show development of an adaptive interface for physician’s data entry of electronic medical record. In this interface, he developed short menus that provide likely selection to user using machine learning technique. The results of this paper indicate use of machine learning for development of data entry applications.

The usability study conducted by Sears et al. [10] indicates that split menus reduces the performance time by 17–58%. Thirteen participants were involved in this study. Two different menus designs traditional menu and later slit menus were used by participants for four weeks each. The program created split menus for the font menus (containing 28 items) in MacWrite and Microsoft Word were installed on Macintosh computers at two sites. The statistical *T* test shows that split menus resulted in faster mean selection time for each menu and faster selection time for several individual fonts. Also during usability test, out of 13 participants, nine preferred the split menus.

The literature suggest that, intelligent methods (like machine learning, i.e., probabilistic approach and artificial intelligence) can be used in design and development of user interfaces for data entry.

3 Methodology

The literature specifies that intelligent approach can be adopted in designing the user interface for the data entry. Therefore, we hypothesize that ‘Quantitative Probabilistic Widgets’ or Dynamic widgets improve the performance of the data entry. To test the above hypothesis we have conducted an experiment as given below,

3.1 User Study

The ‘quantitative probabilistic widgets’ were implemented, as illustrated in Fig. 2 and a user study was conducted for its usability evaluation. We have conducted an experimental study measuring the improvement in the accuracy and speed in a real-world data entry environment.

3.1.1 Context and Participants

To carry out this research we have selected two Rural BPOs from the rural part of Maharashtra-western side state in India. Ninety five participants (50 males, 45 females) working in R-BPOs belonging to the age group of 18–30 years (average 24.9) were recruited. Almost all the participants were from the rural background with primary education (up to 10th) in their mother tongue (*Marathi* language) and minimum three months of data entry work experience. Figure 1 depicts the participants performing given experiment.

3.1.2 Instrument

A specially designed user interface was used for this experiment. The user interface was divided in two parts/screens/forms. Both parts were designed according to layout of the 'banks' account opening form' and only 'personal information' column. The 'personal information' includes name, address, PIN code, date of birth, gender, etc. The difference between first part and second part is that, first part of interface was named as 'existing interface' and designed based on static fields/widgets. The second part of interface was designed using dynamic widgets. For example, 'Date of Birth' field was provided with the 'bar chart' indicating quantitative probability of existing entries for different age groups like 'below 18 years', '18–60 years' and 'above 60 years' and another data entry widget or radio button named as 'Gender/Sex' was supported with the numeric probability for particular gender. This type of practice can help operator to cross validate and hence speed up their performance while data entry. In this paper, study of only two dynamic widgets has been stated. Figure 2 depicts screen shot of quantitative probabilistic (or dynamic) widgets.

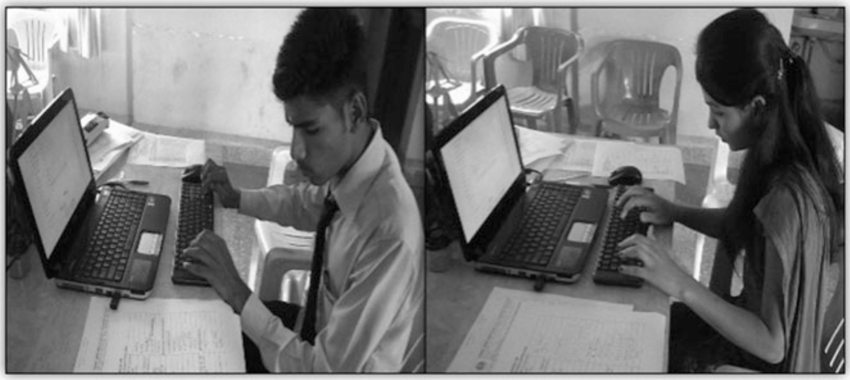

Fig. 1 A picture showing participants performing the experiment of data entry

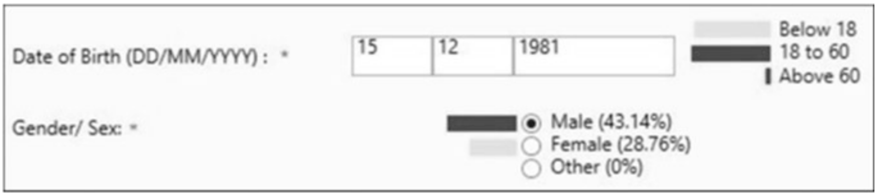

Fig. 2 Screenshot of quantitative probabilistic widgets used in data entry, first widget of 'Date of Birth' entry shows the quantitative probability for different age groups and second 'Gender/Sex' radio button is supported with numeric probability for particular gender

3.1.3 Experiment Design

The user experiment was designed as a within group study. In user study, independent variable is widget design having two types as existing (or static) widgets and quantitative probabilistic (or dynamic) widgets. The dependent variables are error and time. To evaluate the performance of both data entry widgets, the entry time and error rates were measured in the usability evaluation session.

3.2 Procedure

Prior to actual experiment, the participants were explained about the design and purpose of dynamic widgets and also provided practice session on it. The experiment was divided into two tasks—one is data entry on existing interface (having static widgets) and other on designed interface (having dynamic widgets). The tasks consist of transcription of given paper form into electronic form using both interfaces. Participant was instructed to perform the tasks as quickly and accurately as possible. The computer-based background recording of each participant interaction with the designed user interface have taken for calculation of the accuracy and speed.

4 Results and Discussion

We have collected 190 form entries, each form having 17 widgets but only two widgets entries were analysed for calculation of accuracy and time. In total 32 errors were observed, 27 errors in 'Data of Birth' widget and five errors 'Gender/Sex' widget during both interfaces data entry.

The statistical paired t test suggests significant difference in the total time required for the data entry using static widgets (mean = 12.39, SD = 1.91) and dynamic widgets (mean = 12.06, SD = 1.82), $t(95) = 3.72$, $p = 0.000$. It was also observed that errors during static widget data entry (mean = 0.05, SD = 0.22) were significantly higher compared to dynamic widgets (mean = 0, SD = 0), t (95) = 2.29, $p = 0.025$. Therefore, the operator required less time with more accuracy using dynamic widgets compare to traditional design of widgets (also called as static widgets) during data entry. Therefore results indicate that use of quantitative probabilistic widgets (also called as dynamic widgets) can improve the performance of the operator.

The results show considerably faster (31 s) performance by quantitative probabilistic widgets in comparison to the static widgets. It was also observed that operators were made more number of errors in static widget ('Gender' widget). This was because during static widget entry the participants took more time to cross validate the entries with original form entry, but in case of dynamic widgets sometime they ignore the cross validation of entered data and therefore make faster entries.

5 Conclusion

There are significant differences in the speed of entry and slight difference in the error rate for two experimental conditions of the data entry. This upholds our hypothesize that, 'Quantitative Probabilistic Widgets' improve performance of data entry. Therefore we conclude that probabilistic approach can be used to design intelligent user interfaces for data entry which help to improve data quality.

Acknowledgements I would like to thank the Rural BPOs like, *Source2Rural, RuralShores* for their participation in this experiment. Also I would like to extend my thanks to Prashant Salve and Priya Salve for their involvement in data collection.

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Part VII
Cognitive Ergonomics

Chapter 36
An Eye-Free Android Application for Visually Impaired Users

Uday Sagale, Ganesh Bhutkar, Mahadev Karad and Nikhil Jathar

Abstract There is an exponential increase of mobile phones all across the globe. Most of the mobile phone users prefer touchscreen mobile phones, which may lack adequate accessibility features. These touchscreen mobile phones are also used by visually impaired users and they face difficulties even with basic functionalities like calling and messaging. In this research paper, an eye-free application (App) is proposed for Android phones. It uses ‘Speech to Text’ and ‘Text to Speech’ converters for calling and messaging functionalities. It has a very simple User Interface (UI) providing ample multimodal feedback, action confirmation and audio help for visually impaired users. In future, it can be extended to add functionalities such as multimedia, gaming, navigation and multi-lingual support.

Keywords Eye-free application · Mobile phones · Android · Visually impaired users · Messaging · Calling

1 Introduction

Today, mobile phone has become important device in human life. According to the Telecom Regulatory Authority of India (TRAI), June 2014, there are about 915 million mobile phone subscribers in India [12]. With increasing number of mobile phones, messaging and calling has become an important mean for mobile

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communication. Mobile phone users are of two types—normally sighted and visually impaired users. A visual impairment can be defined as 'loss of sight', that is, total visual impairment or reduced vision [1]. The estimates of World Health Organization (WHO) indicate that there are 285 million visually impaired people in the world, out of which 39 million are totally visually impaired [13].

Eyes play a vital role while accessing touchscreen mobile phones as visual attention is required for such interaction. But, visually impaired users cannot provide visual attention; hence accessibility features are required for them. Table 1 shows problems faced by visually impaired users with mobile phones. To provide solutions to these problems, it is essential to design an accessible interface for eye-free interaction. Such eye-free interface provides user interaction technique which enables user to interact with devices without an involvement of eyes, that is, without visual attention. Hence, we propose one such eye-free interface which is an innovative Android-based Application (App). It helps visually impaired users to access touchscreen mobile phones without using eyes. It has basic messaging and calling features. It uses 'Speech to Text' and 'Text to Speech' converters for user interaction. It is also useful for normally sighted users who cannot look at the mobile screen due to the reasons such as extreme lighting condition (more than 1000 lx) [3], protection of private information, constraint of smaller screen, during walking on the street and others. This research paper, explains design process of the proposed eye-free App.

2 Related Work

To enable visually impaired users to use the touchscreen mobile phones, various eye-free techniques are proposed which include audible screen readers, external memory aids for exploring haptic graphs, non-speech sounds for navigating, two-finger haptic interfaces for touching virtual objects, multimodal feedback for simple computer-based tasks [4, 10]. These techniques make touchscreen mobile phones accessible to visually impaired users to a certain extent. Table 2 shows the eye-free interaction techniques and their applications. These techniques are useful for getting better understanding about eye-free interaction.

Romero et al. has proposed an approach named BrailleTouch in which idea from Braille script is implemented. In BrailleTouch, Braille character cell is imitated to

Table 1 Problems faced by visually impaired users with touchscreen mobile phones

Problem	Problem description
Unable to locate items	Lack of vision makes it difficult to locate items
Difficulty in text entry	Absence of physical keys makes it difficult to locate keys on soft keyboard
Insufficient feedback	Proper audio and tactile feedback is not available
Unable to read data	Visually impaired users cannot read the textual or graphical data

Table 2 Eye-free interaction techniques and related applications

Eye-free interaction technique	Applications
Screen reader	Talks, Mobile speak
Audio feedback	Mobile speak, BrailleTouch
Speech input	Google's speech to text
Gestures	NavTouch, BrailleTouch
Tactile feedback	TouchSense, VBraille

implement six keys on touchscreen mobile phones. Also, as these six keys are placed close to the edge of the screen, it is easy to locate these keys [11]. This arrangement of keys is used in a proposed eye-free App for arranging four keys. Jadhav et al. [8] has suggested the use of 'Speech to Text' converter for the SMS application for Android-based mobile phones. So, the proposed eye-free App is using 'Speech to Text' converter. Kuber et al. has categorized the users as beginners, intermediate and advanced users. Along with the context of use for reading text in mobile phones, this categorization was used as a basis for increasing or decreasing the text reading speed [12]. Therefore, the proposed eye-free App has user types which are Beginner User and Advanced User. Ice et al. has suggested that the auditory feedback might strengthen the sense of community and can result in satisfaction compared to text only feedback [7]. So, audio feedback is provided to the users wherever required. Hoggon et al. [6] has researched that tactile feedback on touch of item and selection of items enables visually impaired users, to locate item on touchscreen. So, this App provides the tactile feedback to improve the efficiency of interaction.

3 Design Considerations

The user survey and identified usability problems with mobile phones are vital inputs to the design of the proposed eye-free App for visually impaired users.

3.1 User Survey

User survey is conducted by interviewing visually impaired mobile phone users in person and through phone. A total of 21 visually impaired users have participated in the user survey. These users include 15 totally visually impaired and 6 partially visually impaired users and are selected through a convenient sampling method [3].

Figure 1 show graphs related with results of user survey. According to user survey conducted, mobile phones are mainly used by visually impaired users for functionalities—calling (100%) and messaging (91%). While almost half of the visually impaired users are currently using interaction method—'Talkback' for accessing mobile phones, majority (85%) of users have also preferred to use this interaction method.

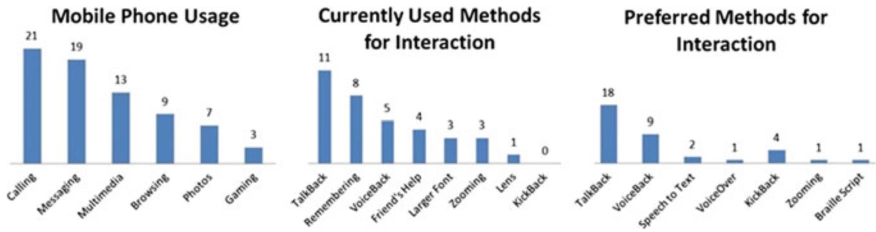

Fig. 1 Graphs related to user survey results

3.2 Problems in Mobile Phones and Their Accessibility Features

Existing mobile phones provide accessibility features like TalkBack and screen readers, which can read the text on the screen, but are not sufficient to provide complete accessibility for visually impaired users. In 'Go SMS' application, there is an unlabelled key at the top of the screen. As the key is unlabelled, it cannot be read by screen readers [9]. Other problems include lack of appropriate help, insufficient feedback [2], no confirmation on actions taken and improper colour combination for colour-blind users.

4 Application Design

The design section consists of two important subsections given ahead.

4.1 Application Architecture

Application architecture of the proposed eye-free App shows Android Framework running on mobile phone and other components on top of it. The two main modules of the application are 'Sending Module' and 'Receiving Module' as depicted in Fig. 2. A 'Sending Module' composes message, sends message, adds/edits contact and makes call. A 'Receiving Module' reads message, receives message, retrieves/searches contact and receives call.

A 'Speech to Text' converter converts the input voice portion into corresponding text while 'Text to Speech' converter converts the input text portion into corresponding voice. A 'Text Conversion Program' converts the text into message/call recipient number which can be then used to send message or make call. A 'Message/Call Conversion Program' converts the received message, caller's name or caller's number into text. The component—'Mobile Services' performs the task of sending and receiving the message or call and is required in both the modules.

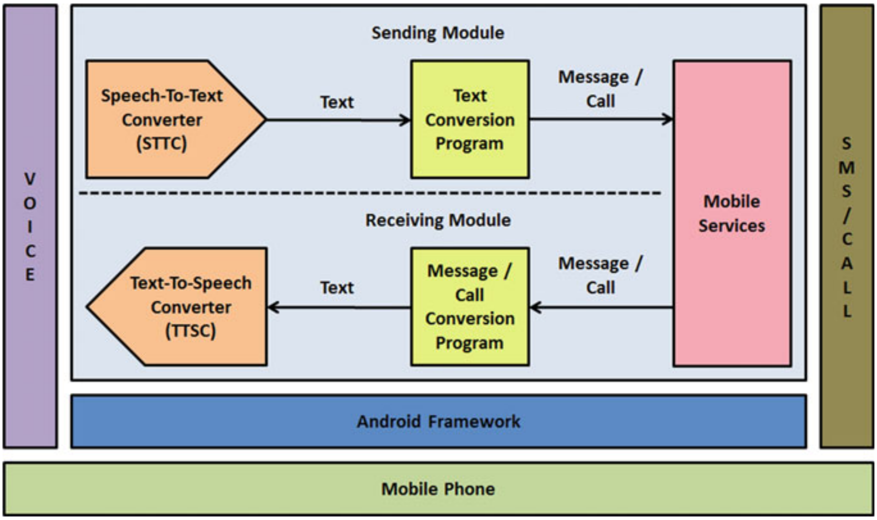

Fig. 2 Proposed eye-free application architecture

4.2 *Proposed Design of Eye-Free App*

An eye-free App is implemented in Eclipse using Android Development Tools (ADT) plug-in [5]. This App works on mobile phones having Android OS versions 4.0 (Ice-Cream Sandwich) and above. It is implemented in landscape screen mode. In this App, each screen has four keys occupying four corners of the screen as shown in Fig. 3. It is easier for totally or partially visually impaired users to locate four corners of the screen with the help of two thumbs. The size of the keys is kept relative to the screen size; so that the App can work on mobile phones of various screen sizes. This App works on 'Speech to Text' and 'Text to Speech' converters supported by Google-provided APIs. The Google Voice is used for 'Speech to Text' converter which requires Internet connection. The 'TalkBack' data is used for 'Text to Speech' converter which has to be downloaded once from Google Play Store and then, can be used without Internet connection. It also provides the audio help on screen—'Application Home', about all hidden functionalities of the application, which enables user to use this eye-free App with ease.

In design of proposed App, the hierarchy of functionalities is provided. The most frequently used functionalities such as Inbox, Call Log and Contact List, are placed first in the key sequence. Also, closely related functionalities such as Settings and message-related or contact-related options are grouped together and placed on the same screen. Only greyscale colours are used in User Interface (UI) of the App. It solves the problem related with specific colours, faced by colour-blind users while accessing the App.

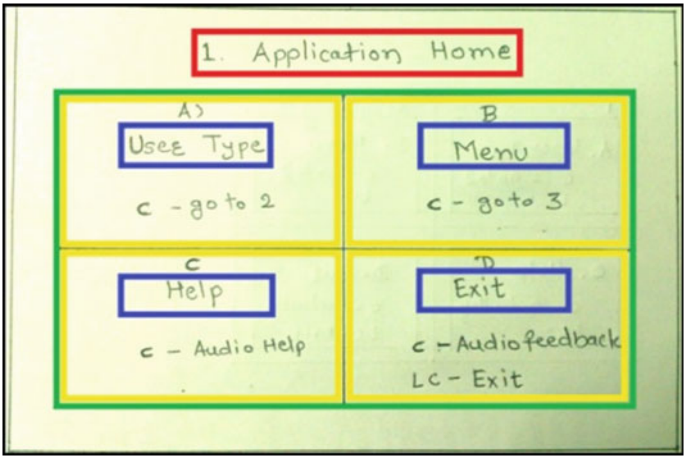

Fig. 3 Paper prototype screens of eye-free App

5 Conclusion and Future Work

The proposed eye-free App is an innovative and useful App for Android mobile phones. It has very simple greyscale User Interface with sufficient multimodal feedback, required action confirmation and audio help for several categories of visually impaired users. Thus, this App makes messaging and calling much more accessible for visually impaired users. In future, the App should be extended to include functionalities such as multimedia, Internet browsing, gaming and navigation support. Other regional and foreign languages should also be incorporated in near future.

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Chapter 37
Meditation as a Countermeasure to Reduce Cognitive Decline During Total Sleep Deprivation

Abhirup Chatterjee, Koushik Ray, Usha Panjwani, Jag Parvesh Anand, Lalan Thakur, Sanjeev Kumar and Debkumar Chakrabarti

Abstract Decline in cognitive functions is a major challenge for professionals during sustained wakefulness. We aimed to evaluate the efficacy of meditation as an intervention in the reduction of the cognitive decline during total sleep deprivation (TSD). Healthy male volunteers (n = 10) drawn randomly from the Indian Army participated in a 4-night study design executed before and after 2 months of meditation practice pre-intervention TSD for 24 and 36 h increased dysfunction rating score (DRS) in terms of a decline in remote and recent memory, mental balance, attention/concentration, delayed and immediate recall, verbal retention, and recognition. Visual retention remained unaltered. Stroop color-word interference (SCWI) showed a decline in 'word' scores after 36 h, 'color' score after 24 h, and 'color-word' score after 24 h TSD. Maze tracing test scores decreased after 24 and 36 h TSD. Post-intervention recordings of DRS no longer showed the decline in remote and recent memory, mental balance, attention/concentration, delayed and immediate recall, verbal retention, and recognition, which was seen without intervention. SCWI improved post-intervention with no significant change in 'word' scores and 'color' scores. However, 'color-word' scores remained low after 36 h TSD. Maze tracing test scores improved post-intervention with no significant change after 24 and 36 h TSD. After recovery sleep, there was a significant improvement in all the above measures. It was concluded that meditation could serve as an effective intervention to reduce the cognitive decline during TSD. The study substantiated the potency of meditation in reducing cognitive decline following TSD.

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Keywords Cognition and total sleep deprivation · Meditation as intervention · PGI memory scale · Stroop color-word interference · Maze tracing

1 Introduction

Modern society is beseeched with the problem of sleep deprivation, due either to night work schedules or to sleep disturbances. Professionals like shift workers, transmeridian pilots, and armed forces personnel are deprived of night sleep while it is very important to maintain cognitive performance during their work schedule. Designing of suitable strategies to reduce cognitive decline during sustained wakefulness is not only an emergent but a crucial need of the hour. Pharmacological interventions like Caffeine and Modafinil have been evaluated, yet the undesirable side effects of regular use of these compounds in high doses cannot be avoided. In view of the above-mentioned considerations, the present study aimed to evaluate the efficacy of meditation in the reduction of the cognitive decline during sustained wakefulness. There are numerous studies depicting the effect of sleep deprivation on cognitive functions. Recent studies suggest that sleep deprivation reduces attentional resources, thus leading to impaired error monitoring thereby increased errors [1]. This has also been evident from event-related potential (ERP) studies that experimental sleep fragmentation elicits impairment in information processing capabilities associated with reduced arousal [2].

Temporal memory is believed to be disrupted by total sleep deprivation (TSD); volunteers display considerably worse insight into their memory encoding performance after TSD [3, 4]. Slow wave sleep (SWS) and rapid eye movement sleep (REMS) contribute to the coordination of complex, emotionally salient declarative memories, and embedded in networks of previously existing associative memory [5, 6]. TSD causes marked reduction in memory retention, indicating the role of REMS in declarative memory consolidation. Motor sequence learning, motor adaptation, and visual perceptual learning are improved after one night of sleep [7, 8]. Learning is even considerably enhanced by daytime naps for about 60–90 min [9].

PGI Memory Scale (PGI MS) is a component of PGI Battery of Brain Dysfunction by Pershad and Verma [10]—a widely accepted test battery to assess organic brain dysfunction. It is highly sensitive, comprehensive, and easy-to-administer test independent of education level and sex to assess different aspects of memory, available in Hindi. PGI MS assesses memory in 10 components—remote memory, recent memory, mental balance, attention/concentration, delayed recall, immediate recall, verbal retention for similar and dissimilar pairs, visual retention, and recognition. Stroop color-word interference task (SCWI) is a unique tool that can test one's selective ability to inhibit conflict responses. The test involves three parts which display a hundred stimuli each: color names, colored patches, and color names printed in incongruously colored ink. Maze tracing (MT) reveals one's planning and decision-making ability along with the added component of perseverance for a given job. Despite the popularity of these tests in neuropsychological research, there are limited reports of SCWI and MT with respect to sleep deprivation [11–17].

Meditation is a discipline by which one attempts to get beyond the conditioned, "thinking" mind into a deeper state of relaxation or awareness. It often involves turning attention to a single point of reference. Meditation is recognized as a component of almost all religions, and has been practiced for over 5000 years. It is also practiced outside religious traditions. Meditation has been defined as "self-regulation of attention, in the service of self-inquiry, in the here and now" [18]. The various techniques of meditation can be classified according to their focus. Some focus on the field or background perception and experience, also called "mindfulness"; others focus on a preselected specific object, and are called "concentrative" meditation. There are also techniques that shift between the field and the object [19]. Meditation has been shown to bring about an improvement in cognitive and motor functions [20]. Previous studies from this laboratory have reported beneficial effects of meditation in normal healthy people and patients of psychosomatic diseases [21–26]. There is so far no report in literature of using meditation as an intervention for cognitive impairment following TSD.

Interventions for cognitive performance after sleep deprivation have been extensively approached with the use of different pharmacological agents like caffeine, modafinil, amphetamine, tyrosine, etc. Most of them have been shown to be variably effective, but the side effects they incur are inevitable. So far, there is no previous effort to improve cognitive performance after total sleep deprivation using any non-pharmacological intervention.

In light of the above information, the present study aimed to evaluate the efficacy of meditation as an intervention, laying a special emphasis on training the mind, on the amelioration of cognitive decline after 24 and 36 h of TSD. It was hypothesized that practice of meditation for 2 months would reduce the various aspects of cognitive decline during TSD including different components of memory, attention, and vigilance as assessed by PGI, SCWI, and MT.

2 Materials and Methods

2.1 Human Volunteers

Ten healthy young male volunteers (21–30 years) with body weight 62.0 ± 4.1 kg and average education level of eighth to tenth standard of the Indian education system (10 years of total education) participated in the study. They had a normal sleep-wake schedule and were free from any sleep, neurological, or cardiac disturbances. They all were nonsmokers and nondrinkers. They did not have any history of intake of caffeine, any psychotropic, psychoactive, or other drugs influencing sleep architecture nor they used any such agent one month prior to the commencement of the study till it was over. All of them were explained the purpose of the study and gave written individual informed consent. The entire protocol was approved by Ethics Committee of the Institute.

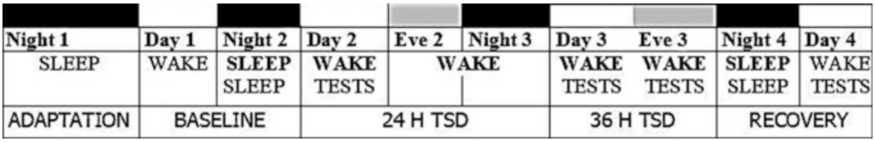

Fig. 1 Design of experiments

2.2 Design

The recording was done in two phases: Phase 1 (Pre-intervention) and Phase 2 (Post-intervention). The recording design was exactly similar for both the phases. For each of Phase 1 and 2, each volunteer participated in a 4-night study design. The first night was adaptation—to make the subject habituated to sleep with the necessary attachments. The second night was baseline; third, 24 h total sleep deprivation and fourth (last) was recovery sleep night. A 36 h total sleep deprivation was obtained by keeping the subject awake for 12 h after 24 h of deprivation. Each volunteer had approx 7.5–8 h of sleep during adaptation and baseline nights and 8.0–9.0 h of sleep during recovery night. They woke up spontaneously at 06:30–07:00 h in the morning following nights 1 and 2, and at 07:15–07:45 h following recovery night (night 4). The design of the experiment has been presented schematically in Fig. 1.

After each phase, i.e., baseline sleep, 24 and 36 h of deprivation and recovery sleep, PGI MS, SCWI, and MT were administered in next morning following baseline sleep, 24 h of deprivation and recovery sleep during 08:00–10:00 h for 36 h TSD, and recordings were obtained in the evening during 19:00–21:00 h. The entire schedule described above was repeated before and after 2 months of meditation practice.

During 24 and 36 h TSD (daytime), subjects were on regular duty schedule involving light physical workload. This was done to assure the homogenous work pattern for them through the period of experiment.

2.3 Protocol

To overcome the learning effect of all the tests, the volunteers were administered enough training and practice sessions before recording the baseline.

2.3.1 PGI Memory Scale

PGI Memory Scale is a highly sensitive, comprehensive and easy-to-administer test available in Hindi and English. Pershad and Verma [10] has reported the reliability and validity of the Hindi version. PGI MS assesses memory in 10 components—remote memory, recent memory, mental balance; attention/concentration, delayed recall, immediate recall verbal retention for similar and dissimilar pairs, visual retention, and recognition. The test is primarily simple questionnaire based and was administered in a calm, quiet environment. The volunteers were asked several questions and problems. The answers were scored using given norms.

2.3.2 Stroop Color-Word Interference Task (SCWI)

SCWI was done in a calm, quiet environment and the volunteers were explained the modality of the test in detail. The test features a three-page test booklet. On the first page (referred to as the 'word' page), the words "RED", GREEN", and "BLUE" are printed in black ink and repeated randomly in 5 columns of 20 words each. On the second page (referred to as the 'color' page), the item "XXXX" appears repeatedly in similar columns, printed in red, green, or blue ink. On the third page (referred to as the 'interference' or 'color-word' page), the words "RED", "GREEN", and "BLUE" are printed in red, green, or blue ink—but in no case do the words and the colors in which they are printed match. For example, the word "BLUE" appears in either red or green ink.

2.3.3 Maze Tracing (Electric)

The maze tracing was also administered in a calm, quiet environment. Volunteers were explained the modality of the test. It contains an electric platform with multiple grids (in a definite row × column arrangement) of two types—touching one by the probe, a sound is heard, this is a false count; and touching the other by the probe a light glows, this is a maze count. The difficulty of the maze was set to a particular level determined by software. The test was administered for 180 s, and total numbers of maze counts are noted at the end.

2.4 Actigraphy

Actigraphy was performed using an Actiwatch™ (AW 64, Mini Mitter, USA) to monitor the activity profile throughout the period of experiment (i.e., 5 days and 4 nights). The threshold activity was set such that even a nap could be detected, as the software for analysis of activity (Actiware™ v. 5.0, Mini Mitter, USA) detects 'awake' or 'sleep' states depending upon that very threshold level of activity. Activity was expressed in arbitrary units. Volunteers wore the Actiwatch™ throughout the day except for the time of bathing. Before and after taking bath, they pressed a button on the Actiwatch™ to indicate the start and the end of the event (bath).

2.5 Intervention: Meditation

This was a 25 min session of spiritual exercise performed by moderate workers on a twice daily basis for 60 days at 07:30–08:00 h and 18:00–18:30 h under the guidance of a professional yoga instructor. Each session consisted of four stages with volunteer sitting in upright position and back erect—first quietly with eyes closed for 6 min. This was followed by the Pranayama “Udgeet”—the respiratory exercise for the next 6 min, in which the volunteer sat with hands in upright position and mouth shut. The index finger was placed on the forehead; with next three fingers covering his eyes and the thumb pressing the earlid. This ensures the feeling of resonance to increase. In this state the person chanted ‘mmmm’ of the ‘Om’ with slow deep breathing. Next 6 min the ‘Om’ was chanted while sitting erect on back and exhaling slowly with the eyes closed. Last 6 min were spent in absolute stillness, wherein the volunteer sat with eyes closed and breathing slowly, again in first posture. At the end, participants raised their hand above their head, rasped the palms first slowly, and then briskly placed the palms over the eyes and the session was completed.

2.6 Statistical Analyses

Values were expressed as Mean ± SE. We have used Graphpad® Instat and confirmed the results using SPSS 13.0. Analysis of statistical significance for changes within groups during various conditions was performed using Friedman’s test, followed by Mann Whitney’s *U* test to analyze the between group significance for a significance level of $p \leq 0.05$.

3 Results

3.1 Effect of TSD on Cognitive Performance

3.1.1 PGI Memory Scale (Table 1)

Dysfunction rating score (DRS, expressed in scores) registered considerable increase following TSD ($\chi^2_{F(3)}$: 21.99; $p < 0.001$ for both 24 and 36 h TSD), which after recovery sleep attained its baseline range ($\chi^2_{F(3)}$: 21.99; $p < 0.01$ for both 24 h and 36 h TSD). Remote memory was impaired significantly after 24 h TSD ($\chi^2_{F(3)}$: 21.66; $p < 0.001$) and 36 h TSD ($\chi^2_{F(3)}$: 21.66; $p < 0.001$), compared to baseline and returned back to normal level after recovery ($\chi^2_{F(3)}$: 21.66; $p < 0.001$ and $p < 0.001$ for 24 h TSD and 36 h TSD respectively). A very similar trend was observed for recent memory, mental balance, attention/concentration, delayed and

Table 1 Effect of meditation on different components of PGI memory scale (dysfunction rating scores) after total sleep deprivation

	BL sleep	Before intervention (Phase 1)			After intervention (Phase 2)		
		24 h TSD	36 h TSD	Recovery	24 h TSD	36 h TSD	Recovery
Remote memory	0.2 ± 0.63	1.9 ± 1.37***###	2.7 ± 0.48***###	0.2 ± 0.63	1.0 ± 0.03	1.2 ± 0.42**	0.5 ± 0.167
Recent memory	0.3 ± 0.95	2.0 ± 0.82***###	2.8 ± 0.42***###	0.2 ± 0.63	1.2 ± 0.91	1.1 ± 0.73	0.3 ± 0.67
Mental balance	0.4 ± 0.84	2.5 ± 0.53***###	3.0 ± 0.06***###	0.3 ± 0.95	0.7 ± 0.48	1.2 ± 0.42	0.7 ± 0.67
Attention/concentration	0.2 ± 0.63	1.8 ± 1.03***###	2.5 ± 0.97***###	0.3 ± 0.95	0.5 ± 0.71	0.9 ± 0.31	0.2 ± 0.42
Delayed recall	0.4 ± 0.84	2.4 ± 0.97***###	3.0 ± 0.11 ***###	0.6 ± 0.96	0.8 ± 0.63	1.2 ± 0.64	0.4 ± 0.69
Immediate recall	0.3 ± 0.95	2.1 ± 1.19***###	2.9 ± 0.32***###	0.3 ± 0.95	0.8 ± 0.42	1.0 ± 0.42	0.3 ± 0.94
Verbal retention similar pairs	0.2 ± 0.63	1.5 ± 1.35*#	1.5 ± 1.35*#	0.3 ± 0.95	1.1 ± 1.19	1.0 ± 0.67	0.5 ± 0.98
Verbal retention dissimilar pairs	0.5 ± 1.08	2.0 ± 0.82***###	2.8 ± 0.42***###	0.4 ± 0.84	1.0 ± 0.47	0.9 ± 0.13	0.3 ± 0.67
Visual retention	0.5 ± 1.08	1.1 ± 1.19	1.3 ± 1.41	0.5 ± 1.08	1.1 ± 1.19	1.3 ± 1.41	0.5 ± 1.08
Recognition	0.2 ± 0.63	1.2 ± 1.31*	2.0 ± 0.82***##	0.5 ± 1.08	1.1 ± 1.28	0.8 ± 0.42	0.4 ± 0.67

Values are Mean ± SEM

Please note the ameliorative effect of recovery sleep; while in the case of meditation, there is no significant change after TSDs as compared to baseline and recovery. There was no significant difference between any value of Phase 2 with corresponding baseline values, nor with their Phase 2 baseline values

*, **, *** $p < 0.05$, $p < 0.01$, $p < 0.001$ compared to Baseline and #, ##, ## $p < 0.05$, $p < 0.01$, $p < 0.001$ compared to recovery, respectively

immediate recall and verbal retention for dissimilar pairs. Verbal retention for similar pairs showed significant increase in DRS after 24 h TSD and 36 h TSD ($\chi^2_{F(3)}$: 7.69; $p < 0.05$ for both) which was reduced after recovery sleep significantly ($\chi^2_{F(3)}$: 7.69; $p < 0.05$ for both, compared to recovery). Visual retention did not register any significant change. Recognition was significantly affected after 24 h TSD and 36 h TSD ($\chi^2_{F(3)}$: 11.54; $p < 0.05$ and $p < 0.001$ respectively, compared to baseline). After recovery sleep, there was significant improvement in comparison to 36 h TSD ($\chi^2_{F(3)}$: 11.54; $p < 0.01$).

3.1.2 SCWI (Table 2)

SCWI registered significant cognitive impairment in terms of decreases in 'word' scores after 36 h TSD ($\chi^2_{F(3)}$: 9.89; $p < 0.05$), which was recovered back to normal ($\chi^2_{F(3)}$: 9.89; $p < 0.05$), 'color' score after 24 h ($\chi^2_{F(3)}$: 14.07; $p < 0.05$) and 36 h TSD ($\chi^2_{F(3)}$: 14.07; $p < 0.01$), which also returned back to the baseline range after recovery sleep ($\chi^2_{F(3)}$: 14.07; $p < 0.05$ for both 24 and 36 h TSD) and 'color-word' score after 24 h ($\chi^2_{F(3)}$: 26.76; $p < 0.05$) and 36 h TSD ($\chi^2_{F(3)}$: 26.76; $p < 0.001$). This also attained its baseline range after recovery sleep ($\chi^2_{F(3)}$: 26.76; $p < 0.05$ for both 24 and 36 h TSD).

3.1.3 Maze Tracing (Table 2)

Maze tracing test revealed severe decrease in maze counts after both 24 and 36 h TSD ($\chi^2_{F(3)}$: 29.43; $p < 0.001$), which was ameliorated back to normal range after recovery sleep ($\chi^2_{F(3)}$: 29.43; $p < 0.001$).

3.2 *Effect of Meditation as an Intervention in Amelioration of Cognitive Functions Following TSD (Group 2)*

3.2.1 PGI Memory Scale (Table 1)

Dysfunction rating score (DRS, expressed in scores) did not register any overall increase following TSD. However, remote memory was impaired significantly after 36 h TSD ($\chi^2_{F(3)}$: 16.32; $p < 0.01$), compared to baseline and returned back to baseline level after recovery sleep. A similar trend was observed for recent memory, mental balance, attention/concentration, delayed and immediate recall, and verbal retention for dissimilar pairs. Verbal retention for similar pairs showed no significant increase in DRS after 24 h TSD and 36 h TSD. Visual retention did not register any significant change. Recognition was not affected after 24 h TSD and 36 h TSD.

Table 2 Effect of meditation on Stroop colour-word interference and maze tracing after total sleep deprivation

	BL sleep	Before intervention (Phase 1)			After intervention (Phase 2)		
		24 h TSD	36 h TSD	Recovery	24 h TSD	36 h TSD	Recovery
SCWI ‘word score’ (no. of correct responses)	67.50 ± 11.424	59.30 ± 8.654*	54.00 ± 9.475**#	72.00 ± 8.097	64.60 ± 11.296	61.70 ± 10.350	68.90 ± 10.440
SCWI ‘color score’ (no. of correct responses)	46.30 ± 7.917	38.40 ± 8.984*#	35.40 ± 7.106**#	48.80 ± 7.927	42.50 ± 8.236	39.90 ± 8.075	48.20 ± 7.569
SCWI ‘color-word score’ (no. of correct responses)	32.40 ± 5.854	25.20 ± 6.630*#	21.50 ± 7.230***#	35.10 ± 6.437	27.60 ± 5.967	22.90 ± 5.763*	34.30 ± 5.774
Maze tracing (maze counts)	98.00 ± 15.463	68.10 ± 14.224***#	46.60 ± 12.131***##	105.00 ± 15.188	95.50 ± 14.714	92.20 ± 13.604	100.10 ± 15.044

Values are Mean ± SEM

Please note the ameliorative effect of recovery sleep; while in case of meditation, there is no significant change after TSDs as compared to baseline and recovery. There was no significant difference between any value of Phase 2 with corresponding baseline values, nor with their Phase 2 baseline values

*, **, *** $p < 0.05$, $p < 0.01$, $p < 0.001$ compared to Baseline and #, ##, ## $p < 0.05$, $p < 0.01$, $p < 0.001$ compared to recovery, respectively

3.2.2 SCWI (Table 2)

SCWI revealed considerable improvement after TSD after meditation, as there was no significant change in 'word' scores and 'color' scores following both grades of TSD. However, 'color-word' scores showed a significant decrease after 36 h TSD ($\chi^2_{F(3)}$: 6.02; $p < 0.05$), and this, as before, went back to normal after recovery sleep.

3.2.3 Maze Tracing (Table 2)

Maze tracing test revealed considerable improvement after practice of meditation compared to the severe decrease in maze counts after TSD in Phase 1. There was no significant change after 24 h as well as 36 h TSD.

4 Discussion

TSD impaired all aspects of memory evaluated in the present study. Different types of mental tasks are differentially vulnerable to the loss of different stages of sleep [27]. Memory required to perform cognitive procedural tasks is affected by the loss of rapid eye movement (REM) sleep on the first night after learning occurs and again on the third night after learning. REM sleep deprivation on the second night after learning does not produce memory deficits [28, 29]. Declarative memory, which is used for the recall of specific facts, is not similarly affected by REM sleep loss [30]. The learning of procedural motor tasks, including those required in many sports, is impaired by the loss of stage 2 sleep, which occurs primarily in the early hours of the morning [31]. However, there is no report of memory evaluation after TSD using PGI MS, which analyzes different components of memory. Our study showed a significant cognitive decline in terms of different components of memory aspects after TSD. Nevertheless, there is again no literature support for the use of meditation as an intervention after TSD, a novel approach used in the present study. Meditation helps to enhance different components of memory by its practice sessions and also by improving selective attention thereby facilitating different processes of memory.

The reports on delay in performance of SCWI after TSD are variable and controversial [11, 12], most of them revealing negative impact of TSD. Stenuit and Kerkhofs [27] have reported inhibition of performance in SCWI paradigm after three nights of sleep restriction in women. However, there is no such study which evaluated SCWI thoroughly and reported about word, color and color-word scores individually. All the studies showed result for color-word component, which is concerned with interference. In this line, our study evaluated SCWI performance after TSD in detail and reported in detail. Further, there is no study on SCWI with reference to meditation as an intervention following TSD. We reported amelioration of SCWI impairment after meditation.

The results of this study confirmed the results of previous studies in which planning was degraded by sleep deprivation [28]. The study protocol used by Harrison and Horne [28, 29] engaged a task called "Master Planner" to assess the planning ability. In the present study, the maze tracing test was used as the measure of planning. A review of the literature failed to reveal prior sleep deprivation studies in which a maze test was used as a measure of planning. Yet, we have used the maze tracing test in our study; because similar types of measures are commonly used to study spatial planning processes in both normal and brain-damaged populations [16], and are accepted as tests for planning ability in the neuropsychology community. With respect to planning, Peterson et al. [31] found that different areas of the brain were activated during unpracticed maze tracing (namely, the right premotor and parietal cortex and left cerebellar hemisphere) compared to practiced maze tracing, which activated the medial frontal cortex or supplementary motor area. The previous TSD studies, as stated earlier, have not evaluated planning by maze tracing, while it is accepted to be a cardinal parameter to assess the planning and decision-making.

Behavioral optimization may have an important role to play in the reduction of cognitive decline after TSD. The abilities associated with meditation practice, viz., to sit quietly, to focus attention, to be motivated and relaxed simultaneously, would play a role in optimizing cognitive functions during TSD. Meditation practice could have a two-way beneficial effect—first, it reduced drowsiness during TSD, as measured by subjective scales like Stanford and Epworth Sleepiness scales (data not presented here); and second, meditation practice improved cognitive functions per se. Meditation is considered as a recommended practice for anyone seeking high-level wellness. These facts have been established for amelioration in cognitive impairment following TSD in this study also. We have shown that meditation improves cognitive aspects even after TSD, which was reflected in nonsignificant changes in neuropsychological correlates (PGI, SCWI, and MT) of cognitive performance even after 36 h TSD.

5 Conclusion

It may be concluded that meditation practice can serve as an effective intervention to reduce different components of cognitive decline following 24 and 36 h TSD. The study thus has direct applications for professional demanding sustained wakefulness.

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Chapter 38
Effects of Bharatnatyam Dancing on the Cognitive Ability of Adult Bengalee Females

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Abstract Bharatnatyam Dancing (BD) has been observed to be effective in facilitating achieving favorable body composition. In this backdrop, an attempt has been made to assess the impact of receiving training in Bharatnatyam on cognitive abilities and postural balance in adult Bengalee females (age 18–30 years). The study was carried out on 33 females engaged in sedentary occupations and receiving BD training, for at least six years and practicing daily for about an hour for 6 days a week after obtaining both individual and institutional consents. Control Group (CG) had 35 females of comparable age, occupation and socioeconomic status, but not receiving training in any form of dance or exercise. Cognitive performance and motor analysis were carried out for individuals of both the groups. The data of BDG and CG were compared statistically. P value less than 0.05 ($P < 0.05$) was considered significant. It was found that the BDG individuals had significantly ($P < 0.05$) favorable cognitive and motor ability in terms of MMSE and reaction time and balance rating, compared to the CG counterparts. It may be concluded that BD helps in maintaining better cognitive and balancing ability.

Keywords Sedentary occupation · Indian classical dance · Bengalee women · Cognition · Mental work load · RT

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1 Introduction

Cognition is a set of mental abilities and processes related to acquisition and understanding of knowledge in terms of attention, memory, judgment, mental work load handling and decision-making [17, 21, 26]. Recent studies suggest that cognitive decline is not a de facto consequence of aging, but rather the consequence of reduced physical activity since their early age [28]. And the technological advancements have not only increased the longevity of individuals [20], but simultaneously indulged people to lead a sedentary life [3]; these impose negative health effects, making it a major public health challenge and thus demanding new policies for facing the challenge. Dance, the rhythmical patterning of body movements, is a form of physical activity that has been a common practice under diverse social circumstances across human cultures worldwide [29, 35]; this sensorimotor activity requiring synchronization of external stimuli and coordination of the whole body with timekeepers like musical beats [10], has been a popular leisure-time recreational activity through ages especially among females in India. In our earlier studies, impact of south Indian classical dance, Bharatnatyam—that involves big and exaggerated movements coupled with graceful turns and leaps; along with memorization techniques—has already been observed to be effective in maintaining favorable body physique [11, 31], cardio-respiratory fitness [5] and motor ability [8]. In this backdrop, the aim of the present study is to study the effects of BD on the different cognitive abilities and postural balance of adult Bengalee females.

2 Methodology

On obtaining permission from the institutions, the study was carried out on consenting adult females engaged in sedentary occupations and receiving training in Bharatnatyam (BDG; $n = 33$) for at least six years and practicing it for a minimum of an hour, 6 days a week. Control Group (CG) had 35 females of comparable age, occupation and socioeconomic status, but not receiving training in any form of dance or exercise. Individuals under regular medical treatment (self-reported) were excluded from the study. Information about their age (year), daily activities, food habits was recorded in predesigned schedule. Socioeconomic status (SES) was assessed using the updated Kuppuswamy scale [25]. The BMI was calculated from the measured stature (cm) using anthropometric measuring kit with an accuracy of 0.1 cm and body weight (kg) using electronic scale with an accuracy of 0.1 kg with individuals in light clothing and without shoes. Cognitive performance analyses in terms of mini mental state examination (MMSE) [18] and reaction time (RT) by a finger selection visuo-tactile task [22] were carried out. Balance test [34] was also carried out for individuals of both the groups. To diminish the inter-observer measurement variation coefficients, all measurements were carried out by the same investigator. The data of BDG and CG were compared, using appropriate statistical tools, to find out any significant difference. P value lower than 0.05 ($P < 0.05$) was considered significant.

3 Results

The study was conducted on 33 BDG and 35 CG adult Bengalee females residing in and around Kolkata. All individuals of BDG and CG were of comparable age and socioeconomic status (Table 1).

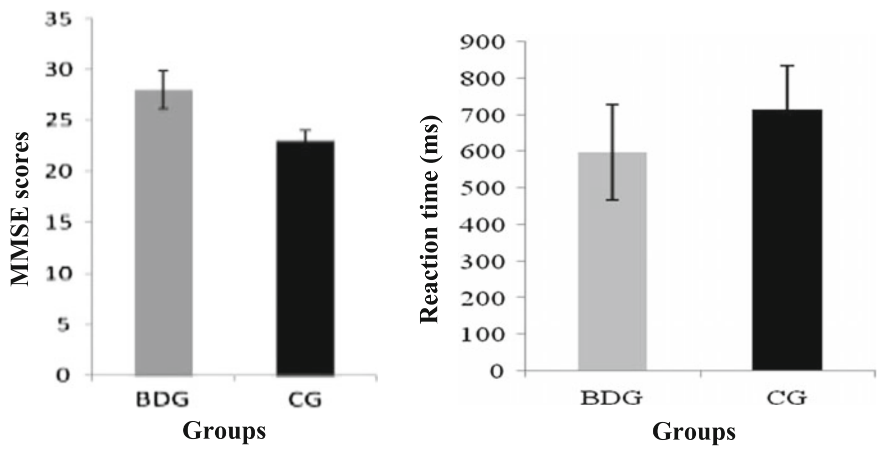
There are significant differences ($P < 0.01$) between BDG and CG individuals in terms of both stature (cm) and body weight (kg) and computed BMI. The cognitive ability assessment in terms of MMSE scores and reaction time measurement were carried out. Significant difference ($P < 0.01$) has been observed between the BDG and CG individuals in terms of MMSE scores and RT (Fig. 1a, b).

The balancing ability is rated in terms of balance ratings of the BDG and CG individuals. It is observed that BDG individuals have significantly better ($P < 0.01$) balance ratings (Fig. 2).

Table 1 Background information of study participants

Variables	BDG	CG
Sample size (*n*)	33	35
Age (years)[a]	24.5 ± 1.45	24.6 ± 0.74
Marital status	All un-married	All un-married
Socioeconomic status[a]	Middle	Middle
Type of exercise	BD	Nil

[a]ns

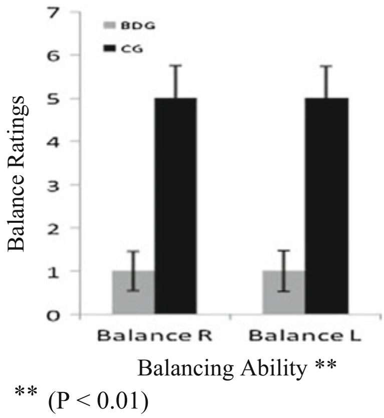


(a) MMSE** (b) RT**

** ($P < 0.01$)

Fig. 1 Comparison between BDG and CG individuals in terms of MMSE (**a**) and RT (**b**)

Fig. 2 Comparison between BDG and CG individuals in terms of balancing ability



4 Discussions

Earlier studies have suggested that physical activity is an accepted stand-alone strategy which addresses many physiological deficits including obesity and its related comorbidities [9, 13, 24], cardio-respiratory abnormalities [1], lack of physical fitness [33]. Our previous studies have already indicated that BD has positive impact on body physique [4, 7, 14, 32], cardio-respiratory fitness [30] and motor ability [8]. The findings of the present study carried out on 33 BDG and 35 CG individuals indicate that the BDG individuals have significantly ($P < 0.01$) higher stature and lower body weight compared to CG counterparts. The mean BMI, an obesity index, of BDG (21.9, normal weight category) is found to be significantly lower ($P < 0.01$) compared to their CG (26.3, overweight category) counterparts (Fig. 1); [3, 4]; hence the CG individuals are at risk for obesity related comorbidities [12, 32, 33]; similar trend of result was also observed in one of our earlier studies carried out with adolescent male football players [6, 9].

The cognitive ability assessed in terms of MMSE scores and RT measurement (Fig. 1a, b); have been found to be significantly better ($P < 0.01$) in BDG individuals, compared to CG counterparts; the MMSE score is higher possibly because of better memory; this may be attributed to the impact of BD as the latter involves remembering retrieving of steps, facial expressions and finger gestures. RT—another common indicator of cognitive ability is significantly lower in the BDG individuals in consonance with our earlier study [8]. It indicates not only a better tactile acuity [23] of the individuals receiving training in BD, but also their improved motor responses. It could possibly be due to the quick movements and concentration that is required in practicing BD. It is also found that the BDG individuals have significantly higher ($P < 0.01$) balancing ability—the ability to maintain the body's center of mass (COM) [12, 36]—(indicated by the lower ratings) in both right and left legs, than their CG counterparts. This may be due to the ability of BD in facilitating betterment of the individuals' somato-sensory system; the latter results in improved motor and sensory orientation. Regular practicing may also increase the strength of lower extremity muscle, which may ultimately improve the stability. It may also be mentioned that individuals receiving training in BD may have a less chance of falling [15, 16, 19], as better balancing ability and RT, a reliable predictor of risk of falls [2, 27], reduce its probability. In the light of findings discussed it may be mentioned that regular practicing of BD may be useful in improving cognitive performance along with improvement in body composition and fitness. It might resultantly facilitate improvement in the task performance, decision-making ability and mental workload handling, which in turn may improve the system performance as it affects the interactions between humans and other elements of the system by intensifying skilled performance, human reliability and expanding human system design.

5 Conclusion

The results of the present study suggested that Bharatnatyam dancing in spite of being a leisure time recreational activity helps in maintaining better cognitive and balancing ability and hence it may be a potential tool, worth implementing in the agenda of regular lifestyle of adult females. If implemented, it may aid in improving the cognitive performance, and also the overall system performance.

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Chapter 39
A Cognitive Approach to Design of Habitats in Extraterrestrial Environments: Review of Literature

Biswaksen Patnaik

Abstract A desire to explore space coupled with an advancing technology has made mankind undertake longer space missions. The confined, isolated, extreme (ICE) environments in the extraterrestrial atmosphere not only affect human performance but also pose adverse effects to emotional and psychological health. Such spaces greatly affect human behavior, productivity and inter-group relationship. With the advent of long duration extraterrestrial travel, the internal environment of the habitat will be of greater importance as compared to short-term missions. This paper describes the effects of ICE environments and various methodologies to cope with them. Cognitive approaches to the design of habitable surroundings have been considered by incorporating various simple yet powerful elements of design such as art, color, shape and form and visual aesthetics. Based on these elements various mitigation strategies, which also include various forms of stress countermeasures, to avoid sensory deprivation and psychological challenges have been portrayed. Various novel strategies such as incorporation of space architecture, aesthetics, soundscape design and nature relatedness have been discussed in tackling problems of ICE environments.

Keywords Extraterrestrial · ICE · Space architecture · Soundscape design · Microgravity · Human factors · Habitability

1 Introduction

Outer space holds one of the most extreme environments and life-threatening conditions. Habitability in space is strongly affected by adaptation to microgravity, isolation, exposure to radiation and user–system interaction hampering human performance, safety and well-being. The level of habitability on space stations, from the Mir to the International Space Station, is reportedly low as until now human factors

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have not been taken into consideration. Integration of sound human factors has become a primary necessity, in particular, considering the approaching scenario of long duration space flights [6]. Habitability Research Group, NASA-Ames' Space Human Factors Office defines habitability as factors which promote productivity, well-being and desirable behavior of crew members in space. Performance is defined as completing a human task in an effective manner. The workload is defined as the amount of physical or mental work assigned for completion during a specified amount of time. Various factors associated with the cognitive capabilities and environment act independently to impair performance and possibly workload and habitability. These include sensory, neuro/cognitive, psychomotor, decision-making/logic/analytical reasoning, emotional state/motivation, psychological adaption, attention/vigilance/awareness, physical adaptation, perceived health and environmental issues [8].

2 Habitability Models

2.1 Models in Aerospace

The Software, Hardware, Environment and Liveware (SHEL) model [6] continues to be one of the most validated models in the aerospace field. This model is based on the interaction among systems such as the Hardware, Software and Liveware. Hardware represents any physical and non-human component of the system, such as equipment, tools, manuals, signs, etc. Software represents any component such as rules, procedures, policies, norms, practices and any other formal or informal rule that defines the way in which the different components of the system interact with each other. Liveware represents any human component in his relational and communicational aspects.

2.2 Models in Space

The most acclaimed model is "Living Aloft, Human Requirements for Extended Spaceflight" by NASA. This model includes factors such as physical environment, health and leisure, privacy and complex effects [6].

Another HF model has been introduced by JAXA cited in a publication by Dr. Takao Yamaguchi—"A human Factors Approach for Japanese Experiment Module Development". The proposed Kibo ISS module is based on four major factors: habitability, operations, physiology and psychology [9]. Here habitability is composed of the factors which provide a shirt-sleeve environment for astronauts living and working inside the space module without wearing space suits. Operation is composed of the factor which provides job support environment for astronauts performing their mission. Physiology is composed of the factors which provide the environment for maintaining astronaut's health. Psychology is composed of the factors which establish a suitable environment for stabilizing astronaut's mental health [6].

3 Human–Machine–Environment System

3.1 Holistic Design

Habitability is an element of the system of which it is a part and not merely a single variable. It is a result of interaction between human, machine, environment and mission. These considerations of the system elements and their interrelations are called holistic design [1]. Holistic design is the result of all aspects and relations of three fundamental components [5]: human (user), machine (artificial component) and environment (natural component).

3.2 Multidisciplinary Design Methodology

Multidisciplinary design methodology focuses on the application of multidisciplinary fields to the space environment with the aim of achieving a positive impact on the quality of life of the people living in extreme environments.

The disciplines incorporated in the methodology are listed below [6]:

- Extreme Design: branch of design that intends to increase the quality of life in extreme habitats at the limits of human survival, to find project solutions and to support cultural expression.
- Space Ergonomics: the application of "human factors" concerning the human–machine interface using scientific knowledge in the design of products, systems and environments meant for human use in outer space.
- Space Anthropology: the study of exaptations (Latin: ex = from and aptus = adapt.), potentialities or archetypes of the functions now needed within the new environment, preexisting in the human species, that allow physical and cultural adaptability to outer space as an aspect of ongoing human evolution and cultural development.
- Space Design: a discipline that aims to contribute to the process of improving living and working conditions in outer space, considering—at the design stage—all the human factors that are essential in creating a personnel-friendly environment that must be comfortable, pleasant and efficient.
- Space Art: contemporary art which relies on space activity for its implementation. In the space habitat, art is able to interact with the feelings and the mood of the inhabitants, opening their minds and increasing their well-being.

- Space Psychology: as a specific topic of Applied Psychology, it “addresses the impact of living and working conditions in space and during space flight on human behavior, performance, mood and behavioral health. It includes basic issues of human adaptation to the extreme conditions in space as well as operational issues of selection, training and support of astronauts”.

4 Role of Visual Aesthetics, Sound and Nature Relatedness

Living in outer space has a deep influence on human life. Isolation, extreme conditions and modified gravity affect humans psycho-physiologically. Astronauts have to uphold themselves on the interior design of a space habitat for their well-being and safety. In weightlessness with a new dimensional cognition visual stimuli as the interior configuration are fundamental to achieve orientation because the vestibular system becomes silent [6].

In microgravity the visual perception is of primary importance to perceive orientation signals, because in weightlessness “people suppress vestibule signals and become increasingly dependent on vision to perceive motion and orientation”. The planning of the ISS interior design is such that, the colors have the function of: “orientation and direction cues”, “on board inventory management”, and “assure psychologically acceptable environment” [4].

Findings suggest that nature relatedness is distinct in producing happiness benefits and bolsters previous suggestions that sustainable behavior and happiness might be simultaneously increased if nature relatedness were facilitated [10]. As another form of stress countermeasure, findings suggest that environmental soundscape control must be considered for long duration missions and space tourism. Use of sounds from nature would be more general and have appeal to all serving as another means of achieving nature relatedness [3].

Using art to improve the astronauts’ living conditions: “If suitable art can be created for a weightless environment, it will not only improve the mental health of astronauts but also inspire people to learn about the universe and space exploration”, explains Ayako [7].

4.1 Experiments in Functional Aesthetics to Enhance Well-Being in Isolated and Confined Settings

4.1.1 Research Objective

Dr. Clearwater and her team demonstrated the physiological and psychological importance of the opportunities to “look out to familiar nature” via simulated window views through a chain of experiments ranging from a mock-up of the space station to hospital surgical holdings. Archival research into existing documentation was also conducted by the research team [2].

4.1.2 Methods Overview

Mounted photographs or backlit transparencies set in different experimental settings were rated by subjects; thereby simulating wardroom mock-up, Antarctic research stations and hospital surgical settings. The photographs were viewed for varying periods of time ranging from less than a minute to over 30 min or up to one year for Antarctic station mock-ups. The ratings were based on preference, interest, familiarity and enhancement. The subjects were also measured for physiological parameters such as blood pressure, heart rate and pupillary dilation [2].

4.1.3 Summary of Findings

Themes portraying photographic landscape with water scored higher than pictures with animals, humans or landscapes. These were correlated with findings describing higher preference levels for images portraying greater apparent depth. Results from long duration Antarctic Station surveys depicted that a variety of Earth-reference cues could serve to combat specific forms of deprivation inherent in confined settings such as the International Space Station [2].

5 Integrated Design Process

Integrated Design Process is defined as a methodology that integrates HF design by combining the principles of interdisciplinary human factors design, user-centered approach and holistic methodology [6].

The first principle [6] interdisciplinary human factors are based on the following factors: Operational factors, physical factors, psychological factors and socio-cultural factors. The second principle [6] user-centered approach is based on Participatory Design (designing together with the user), User Experience (designing the experience of the user) and Empathetic Design (designing as the user). The third principle [6], holistic methodology, is based on the interrelation of human–machine–environment system, Multidisciplinary Team and Concurrent Design.

6 Conclusion

An ideally designed habitat supports the cognition from perception to memory, from unconsciousness to consciousness, it supports human experiences. This paper gives an insight into inclusion of design in the form of integrated design process, nature relatedness, visual aesthetics, participatory design, user experience design, empathetic design, etc. in the design of habitats in extreme extraterrestrial environments. Various factors that enhance habitability in long duration space flights have been portrayed.

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Chapter 40
Mental Fatigue Quantification by Physiological and Neurophysiological Techniques: An Overview

Rajesh Kumar, Parveen Kalra and A.K. Lall

Abstract Mental fatigue needs to be an essential part of industrial engineering and ergonomics. Risk assessment techniques like OCRA, REBA, etc., digital human modeling like DELMIA, RAMSIS, etc. and work station design in industry, etc., all should incorporate mental fatigue as a basic constituent. This is possible only if quantitative value of the mental fatigue is available. This is a major challenge to researchers and a focused effort towards this end is underway. Procedures of quantification of mental fatigue based on physiological and neurophysiological techniques right from their inception to date have been discussed in this paper. The usage of weighted mental fatigue indices so developed for mental and physical work also has been discussed.

Keywords Mental fatigue · Physiological techniques · EEG signals · Weighted fatigue indices

1 Introduction

In the field of industrial engineering and ergonomics, quantitative evaluation of mental fatigue is essential for objective testing of individual cognitive capacity while performing physical tasks under real and simulated work conditions. This ensures that it does not result in mental burnout in the long run. Scientific quantification of

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mental fatigue has always remained a major challenge to researchers. The approach to evaluate mental fatigue has different ways, psychological/physiological as well as neurophysiological. The psychological/physiological approaches have limitations of subjectivity and the neurophysiological techniques have signal processing as a major bottleneck. Although there is lot of work underway on signal processing, a foolproof quantitative technique as yet is not available. Approximate entropy, fuzzy approximate entropy, Kolmogorov entropy and Lyapunov exponent are some of the latest techniques which are helpful in correlating mental fatigue from EEG signals.

This paper serves as an overview of the literature on the quantification of mental fatigue in terms of changing weighted indices extracted from physiological and neurophysiological methods with increasing effort and time. Grandjean (1980) [14] gave the idea that the state of reduced mental alertness that affects performance which is the beginning of an effort toward quantification of mental fatigue. Lundberg and Frankenhaeuser [23], Arienset (2001) and Bongers et al. [7] have found that time pressure, lack of control over own work, low-status jobs, work stress, low supervisor support, conflict at work, low job security, limited rest break opportunities and job schedules result in mental stress. This develops the need to have some probe which measures the amount of mental stress and thereby mental fatigue we develop. Though there are only a few studies measuring brain activity available in light repetitive task using electroencephalography (EEG), yet most of the studies have been conducted to measure drowsiness, fatigue on driver, mental work and not on general mechanical tasks.

2 Methodology

The study is presented item-wise and not year-wise. While doing extensive literature survey, it is found that the quantification of mental fatigue is carried out using mainly physiological and neurophysiological techniques. In physiological techniques, questionnaires, subjective rating of fatigue on accepted scales, reaction time changes on prescribed mental tasks, eyelid closure and head nodding recording during task, etc. are used for quantification. Meanwhile in neurophysiological techniques such as computerized tomography (CT), functional magnetic resonance imaging (fMRI), positron emission tomography (PET) based on cerebral hemodynamics (blood flow) and electroencephalography (EEG), magnetoencephalography (MEG) based on electromagnetic activity of the brain are used to study brain. Of these all techniques, EEG is considered fairly good as it is less invasive, more practical with spatial resolution of the order of less than 10 cm and temporal resolution in the range of less than 1 ms [26]. EEG recording followed by decomposition of the signal by ICA into neural and non-neural activities, artifacts filtering, pattern classification, signal segmentation and finally, weighted mental fatigue indices from theses segmented signals are used for quantification. The weighted indices of these consecutive stationary (0–3 s) and quasi-stationary (3–10 s) segments relate to mental fatigue with time. Thus, selection of papers for review is as (1) scales used by different researchers for perceived rating of mental fatigue, (2) EEG signal variation with mental tasks, (3) parameters extracted event-related potential of EEG signals, (4) weighted indices developed using alpha, theta and beta bands of EEG signals, and (5) neurophysiological techniques like approximate entropy, Kolmogorov entropy and Lyapunov exponent.

3 Review

3.1 Physiological Techniques

3.1.1 Scales for Perceived Rating of Mental Fatigue by Physiological Techniques

Scales for rating of perceived exertion: Borg (1962) developed method of rating of perceived exertion while doing physical work. The scale was from 1 to 21 and worked very well when tested for correlation coefficient w.r.t. heart rates during physical work, bicycle ergometer that was used. Borg and Noble [8] modified this RE to 15-grade scale. Values of heart beats from 60 to 200 per min were to match with PRE scale of 6–20. The basis of the scale increases in the value of RPE with an increase in the physical activity. The simplest measure of mental fatigue can be a subjective self-report measure, such as Visual Analog Scale (VAS) (Aicher et al. 2012), Stanford Sleepiness Scale (SSS), Epworth Sleepiness Scale (ESS) (Murray 1991), Karolinska Sleepiness Scale (KSS) (Shahid et al. 2011), PFS-12 [27] and more recently Situational Fatigue Scale (SFS) [37]. Limitation is subjective and situational measurements. Despite some known issues about the subjective bias, the subjective self-report measures are easy to administer and are generally believed to have good reliability and good validity, especially in the setting of clinical assessment when subjects are likely cooperative and faithful in their self-rating. PERCLOS is percentage closure of eyelid. PERCLOS is calculated through images taken by infra-red cameras. Vaca [35] and Dinges and Mallis [12] have used this non-EEG physiological mental fatigue measurement methods to check performance in driving scenarios, but this has some limitations too. For example, they may perform badly when there are considerable movements on the part of the driver and they are not suitable for situations where the subject requires to be mobile due to job demand.

3.2 Neurophysical Techniques

3.2.1 EEG: Technological Basis

The electroencephalogram is a recording of electrical activities in the brain as recorded from electrodes placed on the scalp. The first EEG recordings on human were made by Berger in 1929, although similar measurements on animals had been carried out as early as 1875 by Caton. Soon after the invention of EEG, it has been one of the major tools to investigate brain functionality. In recent years; the EEG-based mental fatigue tracking technology has been a focal point of research. EEG is a common physiological indicator that has been successfully used to study physiological or psychological brain states (like wakefulness, sleep cycles), neural diseases and neural injuries. Among the numerous physiological indicators which have been linked to mental fatigue in the literature, EEG has been shown to be one of the most predictive and reliable techniques. Moreover, using EEG for mental fatigue measurement has many desirable properties: it is an objective, non-obtrusive and efficient mental fatigue measurement method which is well-suited for online measurement and monitoring of mental fatigue. Each voltage signal may be split into standard frequency bands as delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), and beta (12–30 Hz). The EEG is widely regarded as the physiological 'gold standard' for the assessment of mental fatigue.

3.2.2 EEG Signal Variations with Mental Tasks

Cortical deactivation and sleep onset are considered as reference points for manifestation of mental fatigue. Thereby output from neurophysiological techniques as fMRI, PET and EEG may be used as benchmarks for studying mental fatigue during other activities. An effort in this direction has been reviewed where focus on EEG signal output has been studied for onset of mental while carrying out mainly the mental tasks as a few studies are available for general mechanical activities. The main mental tasks for which these studies have been done are Multiple Sleep Latency Test (MSLT), Maintenance of Wakefulness Test (MWT), 0- and 2-back test, Grid Location, Trail-making, Digit span Psychomotor Vigilance Task (PVT) etc. PVT is treated as the gold standard of performance measures. The mental concentration showed changes in the EEG signals, reduction or increase in peak latency and same up and down in the auditory evoked response [29]. These features later were proved helpful in measuring mental fatigue. Kiroy et al. [19], intensive mental work results in significant increase both of slow (delta, theta) and fast (beta) activities. These results are interpreted as reflection of the deterioration of general brain state activity caused by prolonged mental work and the simultaneous additional brain activation to provide sufficient vigilance level. Trejo et al. (2003) did EEG-based estimation of cognitive fatigue and confirmed that fatigue increased and energy decreased over time. Chen et al. [9] showed high EEG signals at occipital region show high correlation with performance. Thus EEG signals can contribute to the efficient design of work-rest schedule. Zadry and Dawal (2010) found mean power of the EEG alpha bands for the F_z–P_z and O_1–O_2 channels were also found to be higher on the high level/load compared to the low level/load for both of the pace and precision tasks. This indicates correlation between mental and muscle fatigue variation of EEG signals w.r.t. variation in the loads. Balasubramanian et al. [3] say mean power alpha activity was significantly high

($p < 0.028$) in the 12th min when compared to 4th min during cognitive task. Real-time classification of EEG spectra of cognitive state was done by Trejo et al. (2010) by another algorithm called partial least square (PLS) to split EEG signal into small sets and process it afterward. Mental fatigue changes showed increased occipital α and frontal θ band power. EEG-based estimation of cognitive fatigue by Trejo et al. (2010) on a task on computer was carried out and response time (RT), amplitude of ERP components P 300, N1, P2 were recorded and power of $P_z\alpha$ and $F_z\theta$ were calculated. RT rose to 7.9 s from 6.7 s. $F_z\theta$ power rose by 29% and $P_z\alpha$ power rose by 44%. Berka et al. [5] in study on task engagement and mental workload conducted mental task like grid recall, mental addition, image learning, etc. The nodes under study were (F_3–F_4, C_3–C_4, C_z–PO_z, F_3–C_z, F_z–C_3, and F_z–PO_z). It showed that EEG workload varied with change in the mental task difficulty level. The EEG workload was quantified from power spectral densities of the selected epoch of 1-s each after filtering of artifacts by Kaiser window with $\alpha = 6.0$. In a study on effects of mental fatigue on attention an ERP study by Boksem et al. [6]. In the study subjective fatigue ratings from physiological technique, θ, lower α EEG band power from neurophysiological technique ($p < 0.001$) increased when reading were collected after exhaustive mental effort of 3 h. On the investigation of the neurophysiological correlates of knowledge worker w.r.t. mental fatigue using FFT on the EEG signal by Okoqbaa et al. (1994) was done to quantify the mental fatigue. EEG of the alert, sleepy minds of shift workers were examined for α and θ mean power densities by Akerstedt et al. [2]. Their values did not show any tangible results which discourage the use of mean power densities as an indicator of sleepiness. Klimesch [20] study supports that in the bands extracted from raw EEG data alpha power increases whereas theta power decreases when the brain is continuously exposed to cognitive loads. The relationship of head size to alpha frequency with implications to a brain wave model by Nunez et al. (1978) showed large headed and older persons produce slower alpha rhythms was main finding of the study. Measurement of mental fatigability by task related spectral EEG by Peter (2009) EDSC, EEG difference spectra on counting has been developed to find ‘EEG fatigability’ for pre and post-task data. Momin and Abhyankar [24] suggested probabilistic models, machine learning models, and finite state machine etc. as fatigue models to monitor changes in vigilance during monotonous tasks.

3.2.3 Important Features on EEG Study ERP-P300

A few ERP studies have been surveyed where evaluation of mental fatigue using feature parameter extracted from event-related potential by Murata et al. (2005) ERP-P300 was used to comment on mental fatigue. The method of extraction of parameter using a principal component analysis and temporal changes of the cross-correlation function between the grand averaged waveform and each waveform were used to estimate mental fatigue. The standard deviation of the time lag and component P300b which resulted in the maximum cross-correlation between the grand averaged waveform and each EEG waveform were found to show mental fatigue. Assessment of mental fatigue during VDT task using event-related potential [33] for P300 signal latency and amplitude were examined w.r.t. changes in quantum of mental and physical work. The result showed the required reflection of cognitive fatigue. The P300 component of the event-related brain potential and mental effort by Ullsperger et al. [34], has been promoted as a valid index for measuring the mental fatigue from the EEG signal. The changes in the P 300 signal were studied for given changes made in the input mental work. The marked changes suggested the usage of P 300 for other studies too. Using a kernel partial least square classifier 13 s long signals of EEG were examined from first and last 15 min long samples at random. Highly accurate model of fatigue was developed from EEG data and visual analog mood scale.

3.2.4 Weighted Indices

Estimating mental fatigue based on EEG and heart rate variability by Zhang and Yu [38] some mental fatigue indices from wavelet packet parameters of EEG, β/α on prefrontal and parietal electrodes and $(\alpha + \theta)/\beta$ on all electrodes were used to measure mental fatigue. Power spectral indices of heart rate variability were found and their correlation with the indices of EEG was looked into. Also on EEG indices support vector algorithm has been applied to find the states of different mental fatigues. Estimating brain load from the EEG by Holm et al. [15] $\theta\, F_z/\alpha\, P_z$ as index of mental fatigue was used to effects of internal (by sleep deprivation) and external loads (changing the complexity of the task) was studied. The p value test showed the expected behavior. Mental fatigue measurement using EEG by Shyhyuehcheng et al. (2009) to measure mental fatigue, β/α and $(\alpha + \theta)/\beta$ indices again were used and compared with psychological rating of fatigue when RT and ER on Eriksen flanker test was performed.

Weighted frequency index for EEG-based mental fatigue alarm system by Punsawad et al. [28]. Here the experimentation has been done on simulated driving condition to predict the mental fatigue with the help of weighted frequency index. The ringing of alarm when the subject feels fatigued mentally is correlated with the increase in the different weighted frequency indices based on power spectral densities of α, θ and β bands extracted from EEG signals. By using only 1-channel EEG at the temporal area of the brain, more than 90% of prediction accuracies are reported compared to the opinion scores of the users. The best index of the all considered is $(0.6\theta + 0.4\alpha)/0.5\beta$ which gives the maximum accuracy in mental fatigue estimation. EEG patterns and chronic fatigue syndrome by Billiot et al. [4] the task under study was mental task only such as serial sevens and eyes closed. Chronic fatigue syndrome was microvolt levels of EEG signals which were examined for 9–11, 5–7 and 8–13 Hz range for both the conditions and θ/β ratio correlation with total fatigue score on profile of fatigue-related symptoms was examined. During serial seven study the peak frequency had negative correlation with the cognitive difficulty rating.

Perception of effort and movement-related cortical potential during weight lifting by Morree et al. [25] the quantification was done by EEG-derived Movement—Related Cortical Potential (MRCP). The amplitude of this potential shows the activity magnitude in the motor areas of the brain. The study under observation was dumbbell lifting and recording of EEG signal at a given protocol. It was found that there is neural correlation between this MRCP amplitude and RPE. This supports the idea that during physical activity central motor command is aware of muscle activity.

3.2.5 Other Measures

Aftanas et al. [1] used Kolmogorov entropy (KE) and Lyapunov exponent for different states of brain activity when it is exposed to emotional video stimulus. Zhang et al. (2009) found KE values w.r.t. cortical laterization for complex mental tasks greater in P4 channel on right than P3 on left indicating significant left parietal lateralization for total frequency spectrum. This finding is helpful in locating the cerebral regions essential for mental task. Zhang et al. (2009), found changes in EEG time-domain Kolmogorov complexity under different mental fatigue state and evaluated mental fatigue using Lempel–Ziv complexity, i.e., value of $C(n)$ which increases with increase in mental fatigue. Zhang and Zheng [41] used mean KE to analyze and localize the cortical lateralization, main indicator of setting in of mental fatigue and found that dominant working area of the brain is not always the same during same task even. Gao et al. [13] used KE for quantification of event-related desynchronization/synchronization (ERD/ERS) in EEG/MEG data analysis in relation to imagination and hand movement on five subjects and found that changes in the values of KE were 83.7% accurate w.r.t. ERD/ERS. Thus Kolmogorov entropy can effectively quantify the dynamic process of event-related EEG. Chuckravanen [10] is another and latest method to study EEG signals during cognitive fatigue. The experiment was performed on 12 subjects with F_z and P_z electrodes on two scalp loci of the international 10–20 system from which EEG activities were recorded and approximate entropy (ApEn) values which are a measure of irregularity of the signal were computed. This was an effort towards development of some correlation between ApEn and mental fatigue, or quantifying mental fatigue. Das says that Lyapunov exponent is applicable for EEG data analysis only if it is of low dimensional chaos, as in case of high dimensional chaos there is some loss of information. Ubeyli and Guler [32] has used Lyapunov exponents of the EEG signals as inputs of the multilayer perception neural networks which has been trained with a special Levenberg–Marquardt (LM) algorithm. The results showed the changes in EEG signals. Hosseini et al. [16] have used Hurst exponent (H) and largest Lyapunov Exponent (λ) for quantifying the interictal and ictal EEG signals. The results showed 97.4% accuracy when compared with benchmark EEG datasets.

4 Results

Some weighted indices have been developed from neurophysiological techniques which are used in finding the trend of variation of mental fatigue with time in research studies. The Kolmogorov entropy: $K = \lim_{T\to 0} \lim_{\in\to 0} \lim_{N\to\infty} \frac{1}{NT}(Kn + 1 - Kn)$, Lyapunov exponent: $\lambda = \lim_{t\to\infty} \lim_{\delta z_0\to 0} \frac{1}{t} \ln \frac{|\delta z(t)|}{|\delta z_0|}$, approximate entropy: ApEn $= \emptyset^m(r) - \emptyset^{m+1}(r)$, mean power frequency variation with time during work, weighted ratio β/α, θ/α, and $(\theta + \alpha)/\beta$ from F_3, F_z, F_4, C_z, P_z, O_1 and O_2 etc. are some of the indices. The physiological techniques such as PERCLOS change in reaction time-RT, subjective rating on scales as SFS, VAS and BMS are also finding applications when they are processed by statistical tools. In quantitative data there are available relative values of weighted indices, Kolmogorov entropy, Lyapunov exponent and approximate entropy of the EEG signals acquired during mental tasks. F (2,25) = 8.6, p = 0.004 for weighted indices from two data sets acquired before and after the task, average power in any band (θ, α, β etc.) = 199.36 and 256.58 μV^2/Hz at different times during the task, P300 amplitudes = 0.55 (SD = 0.1) and 0.68 (SD = 0.1) at different times during the task. Trends of variation of spectral entropy, sub-band energy, intensity weighted mean frequency, intensity weighted bandwidth, spectral edge frequency as decreasing/increasing are some of the quantitative data available. 012,036 (at different nodes as C_z, O_1 etc.) as approximate entropy, −0.54, −0.48, 0.23, 0.6 (at different nodes F_z, P_z, etc.) as Kolmogorov entropy and 0.5084, 0.5088, 0.9581, and 0.9581 as Lyapunov exponents are some of the values acquired from EEG signals at different times during the task. But these values can not be used as absolute and benchmark values for quantifying mental fatigue. These values are generally calculated for a particular task at different points of time, e.g., before, during and after the task. These values justify the trends of mental fatigue and not the absolute values like accepted heart rate, blood pressure, etc.

5 Conclusion

Good practical ways are available to find mental fatigue but every technique has some limitations. No technique, as of now, is complete in all respects which can process the signal from acquisition stage to filtering to segmentation to quantification and finally, development of similarity index of the segmented signal which is the final goal of quantification. Relative quantitative comparison of two data segments is there but absolute values of indices developed for measurement of mental fatigue is still an issue.

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Chapter 41
Role of Language in Transfer of Tacit Knowledge: Case Study of Bamboo Crafts Making Industries in Northeast India

S.P. Ojha and Pradeep Yammiyavar

Abstract The role of the computers has become vital in most of the industries. It is due to the fact that most of the jobs which require manual editing, drafting, designing and modeling have been easily done with the help of the computers. Slowly the shifts have been seen from traditional manual methods to modern-day technological advance computer systems. In this shift the traditional knowledge of the practitioner is getting lost. This can be seen in variety of industries like craft, jewelry, art and agriculture. The people engaged in these industries are seeking certain alternative ways to achieve this traditional knowledge. Previously this traditional knowledge was achieved by practicing with the master which is now achieved using modern technologies and computers. Capturing this tacit knowledge has been one of the major objectives of this ongoing work. The transfer of knowledge from the master craftsmen to the learner takes place with several days of practice. Natural language plays an important part during this transfer. The methods of communication between the craftsman and the apprenticeship occurs both verbally and practically while making the craft. This paper studies the importance of natural language while acquiring the skills by the learner from the master. This paper also tries to find a solution which can be implemented when there is a transfer of the tacit knowledge with language as a barrier. In the case study the language known to the master craftsman is different from that of the learners. The case study deals with one of the widely spoken language in India to the local languages in northeast India.

Keywords Tacit knowledge · Crafts · Linguistics · Knowledge management · Usability

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1 Introduction

Tacit knowledge is the knowledge which is acquired by repeated practice, experience or teaching certain skills to learner [1]. This can be observed in various industries like craft, jewelry, etc. where skills of the labor matter. Acquiring this knowledge has always been an important factor in the industries. For example, a new employee is trained under the hands of an older experienced employee. Shifts in transfer of know-how has been observed from traditional manual methods to modern-day technological advance computer systems. In this shift traditional knowledge of the practitioner is getting lost. This can be observed in variety of industries such as craft etc. [2]. People engaged in these industries are seeking alternative ways of working with computers for utilizing knowledge which was traditionally transmitted from master to apprentice. Capturing this tacit knowledge especially has been one of interest to several researchers.

The main objective of this work is to capture this tacit knowledge which otherwise would perish with the extinction of the master craftsman/skilled labors. This knowledge can then be available in the absence of skilled labor. This paper reports through case studies involving observation and analysis of the transfer of knowledge between craftsmen and their apprentices. The transfer of knowledge from the master craftsmen to the learner takes place over several practice sessions. Natural language plays an important part during this transfer. This paper analyzes the role of natural language in acquiring the skills which otherwise would happen in the paradigm of "seeing and doing". This paper also attempts to find a solution using digital processes which can be implemented when there is a transfer of the tacit knowledge with communicating language as a barrier. The language known to the master craftsman in this case study is different from that of the learners. There are various questions which need to be answered during the study.

- What language was used during the study?
- Did the instructors' language compete up to the level of understanding for the learners?
- To what extent was the language capability influencing the response rate?

The paper is divided into five sections. Section 1 gives a brief introduction to the definition of tacit knowledge and the importance of language in its transfer. Section 2 gives a background of the previous works involved in this area. Section 3 focuses on the methodology carried out in this paper. Section 4 analyzes the results. Section 5 gives an overall conclusion and further scope of research in this area.

2 Background

The distinction between the explicit and tacit knowledge was introduced by Polanyi [3] in 1962 and Nonaka [4] in 1991. Likewise Molander [5] discusses that knowledge can be of two types one is scientific and the other is practical.

This former is based on the theories and descriptions. The latter is gained through practice and apprenticeship.

The above types of knowledge involve verbal communication between the master and the apprenticeship. Johannessen [6] pointed out that the formation and implement of language follows certain rules and theories in it. The author said that language has a vocabulary which consists of logical constants and empirical variables. These constants and variable along with the rules makes a user to make complete sentences to communicate with another user using the particular language. To completely master the language one has to master the rules and the vocabulary. This mastery is possible by practicing the language and using it appropriately at different situation.

According to Pondy and Mitroff [7] language is a kind of technology that helps in processing data. They identified four different roles which language play in an organizational behavior: control of perception, attribution of meaning, facilitation of communication, provision of a channel of social influence. Wittgenstein and Docherty [8] in his studies have pointed out that to understand a particular sentence one has to understand the language. Unless a communicator has through knowledge of the language, he will not be able to express to a situation effectively in that language. The author also remarks that language is like a way of living. He uses the examples of recognition of human faces, the art of pointing the fingers are a kind of understanding of a person. Göranzon and Josefson [9] studied the nurses in Britain and England. The author argued that a great deal of nursing is passed from a senior nurse to a newly joined nurse through apprenticeship. Smith [10] states that apprenticeship is one of the excellent methods to transfer knowledge and common sense to the learner.

While designing a cross-disciplinary project in computer-aided manufacturing Rosenbrock et al. [11] suggested that skills of the operators should be kept in the mind of designer. Operators should have the freedom to shift strategies without losing software support. The tacit knowledge and skill of the operator are used to avert or correct error. Grant [1] studied the transfer of the knowledge in the firms. He suggested four mechanisms of transfer of knowledge within the firm. They are the rules and directives, sequencing, routines, group problem solving and decision-making. He has also suggested that common language is an enhancer of knowledge integration. Lack of the common language is sometimes a significant barrier in the knowledge transfer.

Ancori et al. [12] suggest that absolute truth can be obtained by linear thinking in which the data is turned into knowledge and then the knowledge is confronted with wisdom as shown in Fig. 1.

The author [12] has suggested that there are basic four steps in which the knowledge is structured: crude knowledge; how to use this crude knowledge; exchanges of the knowledge formed in the previous step; how to manage this knowledge. Smith [10] studied the Dhokra artisans of West Bengal, India. The tribe worked on the decorated brassware products created by the cire perdue or lost wax process which is now getting lost. He has suggested that the theory of artificial as proposed by Negrotti [13] can be a pathway in archiving the lost knowledge of

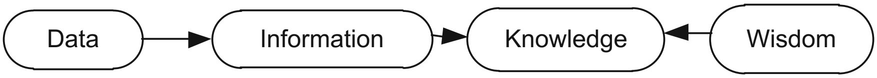

Fig. 1 Linear process of knowledge formation [12]

the craftsman. Their project was involved in creating a multimedia archive of the tacit knowledge of the artisan.

Ambrosini and Bowman [14] report that tacit knowledge is a kind of resource for individuals. The author has again categorized knowledge into two categories: one that is codable and the other which is possessed by the individuals. The author has discussed different characteristics of tacit knowledge one is that it is difficult to write down [4]. Other characteristics of the tacit knowledge is that it is personal, practical (can be described by a process), context specific. The authors have given several methodologies to extract or study the tacit knowledge: Cognitive maps, Self-Q, Semi-Structured interviews, Metaphors.

Several other researchers [15] have also given different techniques of acquisition of knowledge like:

- Action learning
- Informal interaction between people involved in the innovation process

It can be seen from the above that it is very difficult to capture the tacit knowledge since there are various factors involved in it. Language is also a very important factor. Researchers have considered it but very little has been studied in terms of learning the tacit skills. The subsequent section deals with language as factor in the case studies involving the bamboo craft sector.

3 Methodology

Ethnography studies were done with two master craftsmen, who were speaking a different northeast Indian language than the learners who came for learning. The learners were speaking in Garo, Khasi and the craftsman were knowing Assamese, Hindi and Bengali. The hands-on experience of the learners during the making of a bamboo artifact was observed. The analysis of the observation was separately done by comparing it with the learners who had known the communicating language of the master craftsman.

3.1 Case Study I

The bamboo basket making was studied. The two master craftsman's involved were able to speak Hindi, which the learners were fluent with. The Hindi competence learners were 25 in number.

Fig. 2 Basket making by hindi speaking learners. **a** Master craftsman, **b**, **c** learners, **d** one of the final products

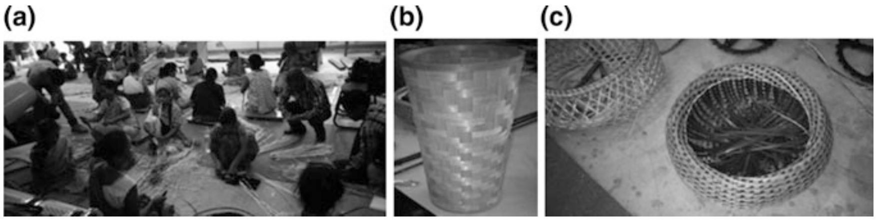

Fig. 3 Bamboo basket making with Garo, Khashi speaking learners. **a** Participants, **b** one of the final products, **c** another final products

Figure 2 shows the basket making by Hindi speaking learners. Figure 2a shows the master craftsman showing the learners how to make a bamboo basket. Figure 2b, c shows the learners practicing with the products. Figure 2d shows one of the final products made by the learners. The interaction between the learners and master was productive, as the learners could easily pick the making of the basket.

3.2 Case Study II

The second case study involved the two master craftsman and 40 participants. The master was able to speak Assamese, Hindi and Bengali and the learners were speaking in Garo, Khasi. It was becoming very difficult to communicate between the participants and the master craftsman.

Figure 3 shows the bamboo basket making process with Garo, Khashi speaking learners. The next section discusses the results obtained from the study.

4 Results and Discussion

The bamboo craft making is considered as the subject of the case study in this paper. The master craftsman who was involved in the study were trained from past 20 years. The participants involved in the case study I were postgraduate students.

Table 1 Comparison between two case studies

Sl. no.	Parameters	Case study I	Case study II
1	Time	1 day	1 day
2	Productivity	2 baskets/day	1 basket/day
3	Knowledge gained	Yes	Yes
4	Interaction with master	More	Less

The participants involved in the case study II were natives of Meghalaya, India and were framer. Table 1 gives the comparison between the two case studies.

The different parameters were studies in Table 1. The time considered to learn one design of basket was 1 day for each of the case studies. The participants were able to produce different number of baskets per day. The participants who were fluent with the master were able to grasp the skill and produce more number of baskets. This brings to a conclusion that the language can drastically change the time limit to learn the skill and adapt it.

5 Conclusions

The main objective of the paper is to study the effects of language during a knowledge transfer process. In this case study, the bamboo basket making is observed. The different learners having different language proficiency were studied. Their grasping of the tacit knowledge from the master was studied considering different parameters. The relevant language competence will help the master as well as the learners to grasp the skills effectively in the shortest time span.

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Chapter 42
Study of Visual Ergonomic Issues in Title Design in Popular Hindi Cinema Posters

Mohammad Shahid and Dharmalingam Udaya Kumar

Abstract Vision is our direct association with the world. Our eyes help us to interact with our surrounding environment in many ways depending on the stimulus it receive from the outer world. Visual communication design has close connection with human vision factor. Indian cinema is defined by the films produced across the country in different languages and Hindi cinema is one of them. Across timeline, film posters have been one of the key modes of film advertisement and title design as its important component. Till early 1990s, before the arrival of digital technology in India, many film posters were designed by artists who never had a formal design education. Through this paper, an attempt has been made to see that, to what extent visual ergonomic issues have been considered in title design of popular Hindi cinema posters. Six key factors—reach, clearance, posture, strength, colour and positioning—have been used to assess the characteristics and ergonomic appropriateness of letters. Result shows that artists have given emphasis over these six factors to address the issue of readability and legibility along with visual appearance.

Keywords Hindi cinema poster · Title design · Typography · Visual ergonomics

1 Introduction

Indian cinema started in the late nineteenth century when the first film show was organized by Lumiere Brothers on 7 July 1896 at Watson's Hotel in Bombay [11]. Indian cinema shows the film culture of different states in different languages. Hindi Cinema is one of the most popular, diverse and successful industry in the world based in Mumbai [1, 6]. It is also popularly known by the name 'Bollywood'.

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Films produced from this industry show pan-Indian culture and released all across the country irrespective of the social class and language. This is the only industry in India which is consumed by the Indian diaspora all across the globe. It shows a very diverse pattern of visual culture and one can experience these through many mediums like film booklets, show cards, lobby cards, handbills, banners and posters [7]. Film publicity is a part of film marketing since the beginning of industry. Across the timeline, film posters have been one of the key mediums for film advertisement. It is a form of mass media [5]. Mass media is a form which works on 'one-to-many' model of distribution, where one cultural text is produced and passed on to many viewers [9]. Being the oldest form of film publicity, film posters still continue to be the popular medium. Film posters are a composition of text and visuals, where the text part mainly comprises of title design, tag lines and credit blocks. In case of film titles, it acts as a logotype and plays an important role in creating brand identity and communicating the theme of the film [2].

Till early 1990s, before the arrival of digital technology in India, many film posters were designed by artists who had never gone through formal design education. They practice this art based on their experience and knowledge gained from artists already in the profession. Across timeline, poster artists have tried to design more effective and persuasive titles by manipulating different parameters like letters reach, clearance, posture, strength, colour, texture, positioning, use of external elements as letters and juxtaposition of image and letters. Out of these, reach, clearance, posture, strength, colour and positioning have a relationship with characteristics of letters and can be analyzed in terms of visual ergonomics. These six factors affect the readability and legibility of letters and play key role in making title design more effective.

Through this paper, an attempt has been made to see that, to what extent visual ergonomic issues have been considered in the title design of popular Hindi cinema posters.

2 Methodology

Hindi cinema does not fall under any defined aesthetics [4]. There is a varied pattern in terms of theme and storyline. To address these challenges only popular films have been selected. In this paper, the titles chosen for analysis are based on popularity criteria and it does not study the popularity of the film and title design. For the study, 1061 Hindi films are colour coded based on sixteen criteria, which defines its popularity (see Fig. 1). These sixteen criteria are majorly based on four groups which are award winning films, milestone films, highest grossing films and critically acclaimed films. From which 191 films having three or more colour codes have been selected from each year for the analysis.

The analysis includes six key factors—reach, clearance, posture, strength, colour and positioning to assess the characteristics and ergonomic fit of typefaces/letters used for title design [10]. Reach refers to the size of typeface or letter, clearance to

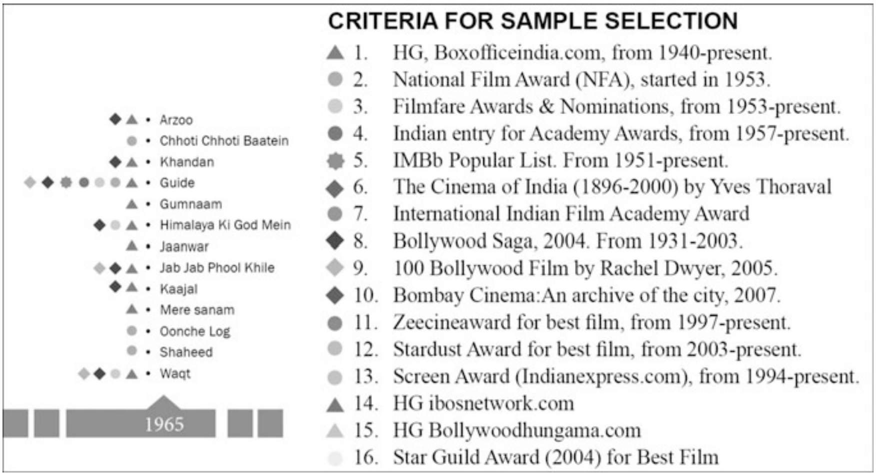

Fig. 1 A sample page from colour coding sheet showing criteria for selection

white space, posture to degree of alignment, strength and colour to visible impact of type and positioning to the site occupied by the title in the film poster. To address the above factors, the *site of title itself* has been considered and a compositional interpretation of the title design in relationship with the s*ite of audiencing* is done. *Site of title* deal with the formal component of the title design where each component acts as an individual sign and create meaning in relation with the other sign whereas *site of audiencing* explores audience behaviour and limitations, and their influence on title design. The framework used for the analysis is based on Gillian Rose model, '*The Site and Modalities for Interpreting Visual Material*' [9].

Content analysis has been used to count the frequency of each factor across the timeline. Here content analysis exclusively enquires about the compositional modalities of the site of title itself which is very much related with the compositional interpretation.

Visual hierarchy is another key factor which has been considered for the analysis. It is defined as arranging a group of visual elements according to their emphasis in the composition. This helps in guiding viewers eye as it scan the design [8]. To establish the visual hierarchy, different factors which should be considered are relative significance of each element in the composition, the nature of the reader, context in which meaning will be made, and the need to create a cohesive arrangement of different forms within the composition. The dominant and subordinate positions of an element in a composition are achieved by its contrasting characteristics [3]. In letterform design, factors which influence the visual hierarchy are size, value/strength, colour, position and proximity [8]. Artists produce hierarchical arrangements in a composition by manipulating these factors.

Table 1 Dominating trends across the timeline

Timeline	Reach	Clearance	Posture	Strength	Colour	Positioning
1930s	High	Low	Straight	Bold	Red, white, yellow, black	Top
1940s	High	Low	Straight	Bold	Red, yellow, white	Bottom
1950s	High	Low	Straight	Bold	Red, yellow, white	Bottom
1960s	High	Low	Straight	Bold	Red, yellow, white	Bottom
1970s	Low	Low	Straight	Bold	Red, yellow	Bottom
1980s	High	Low	Straight	Bold	Yellow, red	Bottom
1990s	High	Low	Straight	Bold	Yellow, red	Bottom
2000s	High	High	Straight	Bold	Red, yellow, white, black	Bottom
2010s	High	High	Straight	Bold	Red, yellow, blue, black	Top

3 Analysis and Result

Result shows that there are significant explorations of above six factors to create more emphasis and to increase the legibility and readability of the title. From Table 1 which shows the dominating trends across the decades, it is evident that to increase the impact of title design on viewers, all the six factors except clearance are utilized significantly to address the legibility and readability.

3.1 Reach

Size of a design element in a graphic space and its size relationship with other elements in the composition contributes significantly in creating emphasis [12]. In majority of the posters, title has been given secondary position in terms of visual hierarchy. In most of the cases taller size typefaces have been used to address the readability and legibility issue (see Fig. 2). Approximately 69% posters show title in uppercase whereas 19% in title case, 5% in lower case and 7% with mixed lettering. Even the small case letters are with larger *x*-height.

3.2 Clearance

It is interesting to see that less emphasis has been given to clearance. In most cases, letters are condensed which is less readable and legible. One reason behind keeping clearance low might be the aesthetics of the title where artist have manipulated the space around the letters to create more visual impact. Figure 3 shows film's titles with low and high clearance.

Fig. 2 Film's titles Anarkali, 1953 and Brahmachari, 1968 with higher reach

Fig. 3 Film's titles with low 'Bobby, 1973' and high 'Lagaan, 2001' clearance

Fig. 4 Film's title with different posture

3.3 Posture

In most cases, the titles are straight and in very few posters they are aligned in either direction to create emphasis and convey the theme of the film. In case of *Barsaat* (1949), title has been aligned towards right to give a sense of falling rain whereas in case of *Bhag Milkha Bhag* (2013), inclined title has been used to convey the sense of speed (see Fig. 4).

3.4 Strength

Strength is defined as the visible impact of type achieved through the contrast of line thickness and boldness [10]. Approximately all the titles show bold lettering with thick strokes. Almost in 82% cases title has been decorated with outline and shadow to create more emphasis. Bold lettering helps title to stand out in a rich colour background and makes it visible from long distance.

Fig. 5 Titles with different positions in poster composition

3.5 Colour

Bright colours mainly red, yellow and white in contrast with the background tone have been used predominantly for titles. Darker tones like black have been used for shadow and decoration purpose to make the title stand out. Yellow colour has been extensively used because of its good visibility.

3.6 Positioning

Placing the most noticeable element near the centre of the composition helps to draw attention to it. But in case of film posters main importance has been given to the visual elements and title occupy the secondary position. Figure 5 shows the three positions utilized for title design in Hindi cinema posters. To keep the title in comfortable range of human vision, 63% of the titles are placed at bottom, whereas 28% at top and 9% in the middle of the poster.

4 Conclusion

The study reveals that, knowingly or unknowingly poster artist have used different techniques to address the ergonomic issues in the title design in Hindi cinema posters. Study shows that artist have given emphasis over *Reach, Posture, Strength, Colour* and *Positioning* to address the issue of readability and legibility. Almost all the titles are in bold lettering with higher reach. It is interesting to see that how outline and shadow effect has been utilized to make it stand out of the background. It suggests that by addressing the above six factors, one can create more readable and legible titles without compromising the aesthetic appearance. It also emphasizes the need of proper visual ergonomics guidelines for designers to make the title design more effective.

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Chapter 43
Research in Driver–Vehicle Interaction: Indian Scenario

Indresh Verma, Susmita Nath and Sougata Karmakar

Abstract Driving is a complex task which requires execution of physical, psycho-motor, and sensory skills. To ensure maximum performance of the driver and for safe navigation of the vehicle, optimal driver–vehicle interaction (DVI) is of utmost necessity. Although, substantial research work is going on in developed countries research activities in this domain is rarely reported in Indian scenario. The current paper presents the holistic review leading to a knowledge-base in the field of DVI research all over the world with a special emphasis on Indian scenario. Present review would be beneficial for the Indian researchers, designers, and engineers associated with automotive industries, to get clear idea about current state of affairs in DVI research in India in relation to the other countries. It would also help them to formulate their research proposal/identify specific field of research in DVI applicable to Indian context.

Keywords Driver–vehicle interaction · In-vehicle information system · Automobile ergonomics · Driver distraction · Safety

1 Introduction

Driving is a complex task requiring the driver to interact with a number of parameters from road traffic to in-vehicle systems and/or displays related to driving. Professional or personal vehicle drivers spend a large amount of time in their vehicle (truck, SUV, passenger car, etc.). Optimal DVI is of prime importance for

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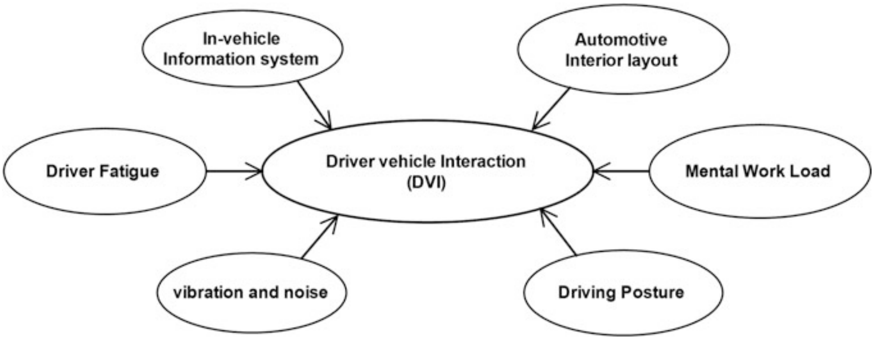

Fig. 1 Components of driver–vehicle interaction

safe navigation of vehicle and ensuring maximum performance (both physical and cognitive) of the driver. DVI deals with the knowledge of interaction of driver with various components of the vehicle and its applications so as to improve the overall performance of driver. DVI is dependent on various factors (as shown in Fig. 1) such as in-vehicle information system, driving posture, driver mental workload, interior layout, vehicle vibration and noise, driver fatigue, etc. While advanced research and development activities related to Adaptive Cruise Control (ACC), Advance Driver Assistance System (ADAS), driver emotion are going on in the developed countries (US, UK, EU, Canada, Australia, etc.); research activities in the developing countries and especially in India are rarely reported. Different automotive companies own their research and development divisions in India, but only limited research findings have been made public. Moreover, DVI research in India is very much essential as driving in India is different in comparison to developed countries in terms of vehicle maintenance, road conditions, traffic rules, driving practices, and anthropometric characteristics of drivers [24].

A clear lack of DVI research in Indian context has been found from the literature review. Additionally, it is observed that the knowledge-base in the aforesaid field is scattered. Hence, there is an urgent need to create awareness for conducting research in this direction to avoid driver fatigue and incidence of accident in India. The purpose for this review article is to provide an insight into the research work done in the field of DVI with special emphasis on Indian scenario. The article also tries to popularise the less explored field of 'Research on DVI' across India among automotive ergonomists, designers, and engineers.

2 Methodology

A comprehensive review of literature was performed and the methodology adopted for this purpose is presented in Fig. 2.

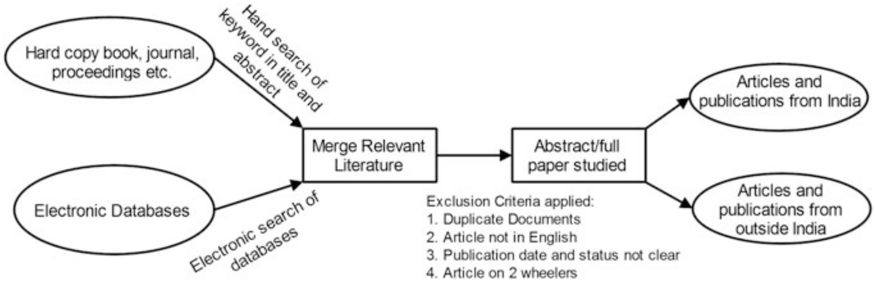

Fig. 2 Flowchart of the search results and inclusion/exclusion of articles

3 Academic and Research Institutions Dealing with DVI Research in India

Few leading educational and research institutions involved in DVI research in India are listed in Table 1.

4 Research on Various Aspects of DVI

4.1 Driver Posture and Interior Layout

One important aspect of DVI is driving posture which is directly or indirectly influenced by interior layout and arrangements of different controls around the driver. To ensure comfortable as well as efficient driving posture, research is going on all over the world. Among various advanced techniques to design vehicle interior in relation to diverse anthropometry and varying drivers' posture, digital human modelling (CAD simulation) is one. It is presently used for ergonomic evaluation of automobile in terms of driving posture, reach, view field, ingress–egress—and interior layout [21, 25]. Moreover, posture of the driver can be

Table 1 List of educational and research institutions working on DVI in India

Educational institutes	Research institutes
Transportation Research and Injury Prevention Programme, IIT Delhi	International Centre for Automotive Technology, Manesar
Dept. of Engineering Design, IIT Madras	CSIR—Central Road Research Institute
Dept. of Mechanical Engineering, IIT Kharagpur	Automotive Research Association of India
Dept. of Design, IIT Guwahati	Institute of Driving and Traffic Research
DYP-DC Centre for Automotive Research and Studies, Pune	National Centre For Vehicle Research and Safety, Rae-Bareli

predicted based on the pre-defined vehicle interior and layout using such techniques [34]. Driving task involves muscular effort for various control (steering wheel, pedal-break, hand-break, clutch, gear, etc.) operations. Driving requires sitting at fixed posture for long hours especially in the case of truck/heavy vehicle drivers. This constraint posture for longer duration may cause muscle fatigue and discomfort. To avoid these situations, truck driver's seat and cabin should be designed using CAD to provide better driver–vehicle interaction [7]. Research is also going on to understand the influence of seat adjustment on the musculoskeletal system using inverse dynamic approach, which helps to analyse the interaction of car seat and human body on different combinations of seat-pan/backrest inclination and the effect of pedal spring stiffness [1].

4.2 Driver Fatigue

Fatigue in drivers is the major cause of road accidents all over world. Hence it is important to evaluate and quantify fatigue. Fatigue can be classified into physical and mental categories. Mental fatigue is more of psychological in nature contrary to physical fatigue which is more of a muscular tiredness. Fatigue causes lack in alertness, reduced mental and physical performance and drowsiness. Multi-modal measures, i.e. surface electromyography (sEMG), electroencephalography (EEG), seat interface pressure, BP, HRV and oxygen saturation level to detect driver fatigue are being used for development of driver monitoring/assistance system [18, 20, 32, 38]. These studies give an insight into the physical and mental fatigue on driver in monotonous driving condition. Driving simulators are used for research on driver mental fatigue, due to its ease and well-controlled conditions for data collection. Drowsiness due to fatigue can lead to incidences of accidents; hence its early detection is desirable. Methods for detecting drowsiness using eyetracking method has been reported [37], consecutively warning signals in form of seat belt vibration are presented.

4.3 Vibration and Noise in Automobiles

Every vehicle exposes its occupants to vibration and noise. These can be due to inherent motion of vehicle and uneven surface on which the vehicle travels. Vehicular vibration and noise are markers of comfort/discomfort of the drivers/occupants. Numerous researches have been carried out in different parts of the world to reduce the vibration and noise that originate from vehicle [11, 14]. Some reported studies on vehicular vibration and noise are also available from Indian researchers. Muzammil et al. [31] studied health impact of vibrations on tractor drivers under variable ploughing conditions. Ingle and Pachpand [17] conducted a community survey on traffic noise among residents of Jalgaon city.

4.4 In-Vehicle Information System

Past couple of decades has seen rapid growth in vehicle electronics and system development. In-vehicle information systems (IVIS) include navigation, entertainment, communication, instruments, and comfort functions. IVIS can provide information about road, weather, navigation, etc. and help in communicating with outside world. Application of in-vehicle devices have made the life of drivers much easy, but also brought distraction from the primary task of driving. This has a tremendous impact on road safety. Research in automotive human factors had a turning point with the introduction of intelligent transportation system (ITS) during 1990s. Various efforts were put into develop integrated driver interfaces for in-vehicle information systems. Effectiveness of menu and control type for IVIS has been studied by Kim et al. [22]. Many automotive manufacturers are using touch gestures used in mobile devices to operate IVIS [23]. Recently, use of multi touch LCD displays in information and navigation system is widely adopted. Research is being carried out towards development of various types of head-up displays (HUD) and its effect on driving [19]. Use of laser-based dynamic active display (DAD) to reduce distraction and visual clutter of the driver has been explored [9]. Recently, studies on use of auditory, tactile cues, and usability evaluation techniques for IVIS have been reported [2, 16].

4.5 Distraction and Safety

Driver distraction occurs when driver performs task other than the primary task of driving. Distraction is often related to accidents and reduced safety. A distracted driver has low response to traffic events, and more likely to apply emergency brakes [15]. Driver distraction can be visual, cognitive, physical, or auditory. Workflow models of major driving manoeuvre is helpful in maintaining safety, development of ADAS and driver training [33]. The safety perception of the devices being used while driving is of prime focus. Safety cannot be directly measured, so some indirect measures of safety related effects induced by a device is employed. Measures of distraction [13] can be categorised as primary task performance, secondary task performance, physiological measure and subjective assessment. Eye glance behaviour has been considered as another measure as visual behaviour is important to driving task. Effect of using mobile phone, navigation systems, and text message on distraction [6, 35] has been reported. Age, gender and driving experience [26, 36] also affect distraction. Research on visual traits/behaviour of drivers is essential to ensure safety of commuters. In India, research has been carried out on visual traits of heavy vehicle drivers of different age groups and vision related tests were performed (e.g. visual acuity, night vision test and glare recovery test). On the basis of this study special screening and training facilities for heavy vehicle driver has been recommended [3, 5].

4.6 Driver's Mental Workload

The idea of workload is the inability of the operator to cope up with the requirements of the task, and that workload measurement is the indicator of the task performance based on operators' capabilities [12]. General characteristics and techniques to measure drivers' mental workload are already being mentioned in detail [8]. Driver's mental workload is categorised as the characteristics of driver, vehicle or surrounding environment. Driver's characteristics include age, anthropometry, visual traits, weight and cognitive characteristics like behaviour, safety perception, information processing. Relation between driver's reaction time with age and mental workload [29] is being reported. Driving primarily requires visual attention; therefore visual scanning pattern to assess mental workload [28] is important. Methods for assessing mental workload by using physiological indices such as eye-fixation duration, EEGs, ECGs, EMGs, BP, etc. have been reported [10]. Subjective assessment of workload using NASA-TLX is also widely being used [10, 30]. Performing secondary task while driving affect mental workload of drivers, effect of Single versus dual secondary task performance have been reported [27, 30]. Environmental characteristics outside the vehicle environment like road, weather condition and traffic signal/signage also influence mental workload. Some reported studies from Indian researches on effect of environmental condition on mental workload are available. Chakrabarty et al. [4] examined the effect of extreme weather on visual and driver behaviour on Indian road conditions. Results revealed that road safety and capacity both decreased due to sudden reduction in visibility and an increase in driving time during rainy season.

5 Future Scope

Future research avenues which need to be explored are vast, since there is lack of sufficient reported studies in Indian context. Research institutes and industries needs to collaborate for better design modifications and understanding the dynamics of DVI. Road map for future research initiatives including setting up of research laboratories with state of art facilities, e.g. driving simulators, ADAS, HUD, CAD and digital human modelling software, virtual reality, 3D motion analysis system, 3D body scanner eye-tracker, EEG and fMRI, etc. Research work in the purview of the impact of weather condition is found from studies conducted in developed nations; hence attention must be focused to extend the similar knowledge-base in Indian context. A collaborative framework involving government, industry and academia must be started to take forward research in driver–vehicle interaction for the benefit of all concerned. Awareness about DVI and its applications could be imparted among scientists, engineers, designers and entrepreneurs through organising seminars, conferences, workshops, etc. on this topic. Currently, research in DVI in Indian scenario is very limited and mainly confined to physical ergonomics aspects concerning driving posture and fatigue (due to vibration, noise, improper seat design, inappropriate occupant packaging, etc.). Hence, for future research, emphasis should be given on other aspects of DVI, viz. driver distraction, mental workload, situation awareness, and safety perception for Indian drivers. DVI in terms of environment monitoring system, advance driver assistance system (ADAS) needs attention in Indian context, since these are the emerging technologies in the future vehicles. Mobility of older adults also needs attention considering growing number of aged population in India. Extensive research thrust to be given in the direction of usability analysis of in-vehicle systems and better modalities of information presentation without causing distraction leading towards enhanced transportation safety.

6 Conclusion

Summarising all aspects discussed in the above sections, it is clear that research in the field of DVI is still in its infancy state in developing nations like India and much work needs to be done. A proper and systematic approach requires to be developed to explore the research avenues relating to DVI in India and other developing countries. It is expected that present review would evoke research interest among Indian ergonomists, designers and engineers associated with automotive industries to take up research endeavour in DVI.

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